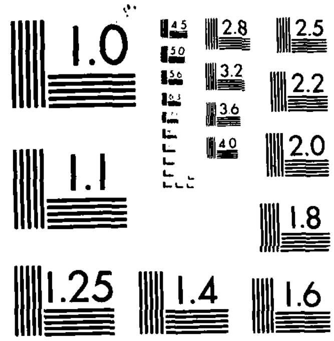
AD-A125 794 RECORDING FATHOMETER TECHNIQUES FOR HYDRILLA DISTRIBUTION AND BIOMASS STU..(U) FLORIDA UNIV GAINESVILLE AQUATIC PLANTS RESEARCH CENTER 1/1

UNCLASSIFIED J V SHIREMAN ET AL. JAN 83 WES/MP/A-83-1 F/G 8/1 NL

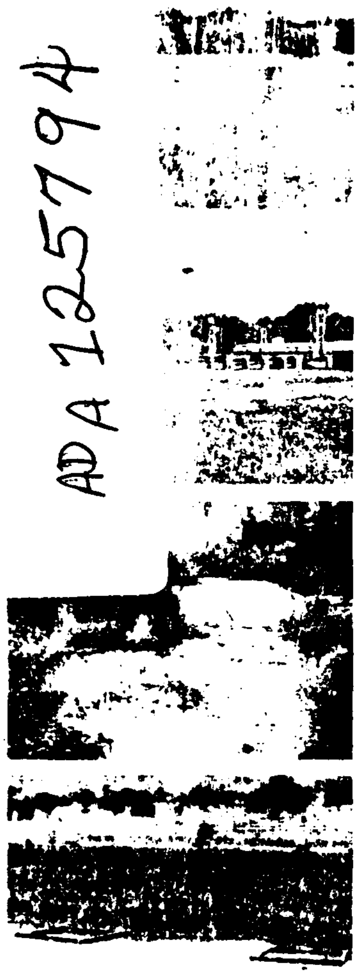
END

FILMED

DTIC


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

AD A125794



MISCELLANEOUS PAPER A-83-1

RECORDING FATHOMETER TECHNIQUES FOR HYDRILLA DISTRIBUTION AND BIOMASS STUDIES

By Jerome V. Shireman, Michael J. Macéina

Aquatic Plants Research Center
Institute of Food and Agricultural Sciences
University of Florida
Gainesville, Fla. 32611

January 1983

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for U. S. Army Engineer District, Jacksonville
Jacksonville, Fla. 32201

and Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under Contract No. DACW39-80-C-0035

Monitored by Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Miscellaneous Paper A-83-1	2. GOVT ACCESSION NO. AD-A125 794	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) RECORDING FATHOMETER TECHNIQUES FOR HYDRILLA DISTRIBUTION AND BIOMASS STUDIES		5. TYPE OF REPORT & PERIOD COVERED Final report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Jerome V. Shireman Michael J. Macéina		8. CONTRACT OR GRANT NUMBER(s) Contract No. DACW39-80-C-0035
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Florida Institute of Food and Agricultural Sciences Aquatic Plants Research Center Gainesville, Fla. 32611		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Aquatic Plant Control Research Program
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer District, Jacksonville Jacksonville, Fla. 32201 and Office, Chief of Engineers, U. S. Army, Washington, D.C. 20314		12. REPORT DATE January 1983 13. NUMBER OF PAGES 56
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) U. S. Army Engineer Waterways Experiment Station Environmental Laboratory P. O. Box 631, Vicksburg, Miss. 39180		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aquatic plants	Lake Baldwin	Sport fishery
Ecology	Lake Orange	White amur
Fathometer	Lake Pearl	
Hydrilla	Regression	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Quantitative vegetation parameters are presented to calculate hydrilla cover and biomass. It is recommended that several of these parameters be utilized to describe hydrilla relationships in a lake. Predictive equations were formulated for the three study lakes and it was concluded that the independent values taken for biomass did not indicate similar relationships in each lake. Differences in subsurface light intensity, water chemistry, and substrate types may cause differences in hydrilla growth patterns which are

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued).

not detectable with the fathometer. Plant density appears to be a major variable in determining plant biomass using fathometer tracing characteristics.

Further investigations to determine the relationship of plant density at various depth intervals and different bodies of water should be incorporated into the current equations to improve predictive capabilities.

Studies were conducted to document temporal changes in white amur and native fish populations and aquatic plant distribution associated with the introduction of white amur. White amur capture techniques including electroshocking, block netting, gill netting, and haul seining were investigated in Lake Baldwin. Although white amur were collected by all methods, none was considered effective. Two distinct white amur size classes were evident.

Hydrilla consumption rates were determined for Lake Baldwin white amur. Effective control was obtained with 185 kg fish per ha of hydrilla.

Native fish were collected with both block nets and electrofishing gear. Small forage fish were dominant and harvestable sport fish composed a small percentage of total fish biomass. The data, however, indicate that Lake Baldwin has a harvestable bass population of 30.5 kg/ha. Condition factor analysis of largemouth bass, bluegill, and redear sunfish indicates that condition values are lower than the national average and are related, to some extent, to the amount of hydrilla present.

A

PREFACE

The work described in this volume was performed under Contract No. DACW39-80-C-0035 between the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., and the University of Florida, Gainesville. The work was sponsored by the U. S. Army Engineer District, Jacksonville, and the Office, Chief of Engineers, U. S. Army, Washington, D. C.

This report represents the annual progress achieved toward completion of the contract and was written by Dr. Jerome V. Shireman and Mr. Michael J. Macéina of the University of Florida. The report is composed of two discrete sections. The first develops a method for estimating aquatic macrophyte biomass using a recording fathometer at three sites. The second section describes biological studies conducted in Lake Baldwin to document temporal changes in white amur and native fish populations and to analyze aquatic plant distributions associated with the introduction of white amur.

The work was monitored at WES in the Environmental Laboratory (EL) by Mr. Eugene Buglewicz and Dr. Andrew C. Miller under the general supervision of Mr. B. O. Benn, Chief, Environmental Systems Division. Mr. J. L. Decell was Manager of the Aquatic Plant Control Research Program; Dr. John Harrison was Chief of EL.

Commanders and Directors of WES during the conduct of the work and publication of the report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

This report should be cited as follows:

Shireman, J. V., and Macéina, M. J. 1983. "Recording Fathometer Techniques for Hydrilla Distribution and Biomass Studies," Miscellaneous Paper A-83-1, prepared by the University of Florida, Gainesville, Fla., for the U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

CONTENTS

RECORDING FATHOMETER TECHNIQUES FOR HYDRILLA DISTRIBUTION AND BIOMASS STUDIES

PART I: FATHOMETER STUDIES

Introduction

1. Aquatic macrophytes are an integral component of freshwater ecosystems; however, excessive amounts of vegetation can alter fish populations, limit recreational use, create health hazards, and block navigation and irrigation routes (Blackburn 1975). The introduced submersed macrophyte, hydrilla (*Hydrilla verticillata*), exists throughout 250,000 ha of Florida's water, and is reported in nine other states including California (Shireman and Haller 1979). In order to evaluate various hydrilla control methods, quantitative data pertaining to the distribution and biomass of the plant must be obtained.

2. Direct contact methods to measure submersed vegetation biomass including point-line transects, SCUBA, and various grab biomass samples are costly, labor intensive, and, in many cases, do not adequately sample larger bodies of water. Color and infrared photography have been employed successfully as remote sensing techniques to map the coverage of aquatic macrophytes (Almkvist 1975; Shima, Anderson, and Carter 1976). However, Spooner (1969) and Benton and Newman (1976) report that photographic methods were not successful when determining submersed vegetation biomass. Macéina and Shireman (1980) utilized a recording fathometer to generate accurate quantitative data on hydrilla coverage and height and to correlate tracing characteristics with actual hydrilla biomass. The recording fathometer used proved to be an economical and feasible remote sensing sampling technique in lakes with a hydrilla monoculture.

3. The objective of this research project was to refine and test the earlier techniques presented in two other lakes and to correlate actual hydrilla biomass with tracing characteristics. Three correlations are compared to those originally reported from Lake Baldwin.

Description of Study Areas

Lake Baldwin

4. Lake Baldwin, located in Orlando, Florida, adjacent to the U. S. Naval Training Center, is an 80-ha lake with a maximum depth of 7.7 m and a mean depth of 4.4 m (Figure 1). The bottom sediment consists of 60 percent sand and 40 percent muck by area (Shireman and Gasaway 1976). Cattail (*Typha latifolia*), panicum (*Panicum hemitomen* and *P. repens*), and waterhyacinth (*Eichhornia crassipes*) fringe portions of the shoreline. Hydrilla was the dominant submersed macrophyte in early 1979 with 71 percent coverage (Shireman and Macéina 1979a). Water control structures at the lake outlet allow minimum water level fluctuation (0.2 m).

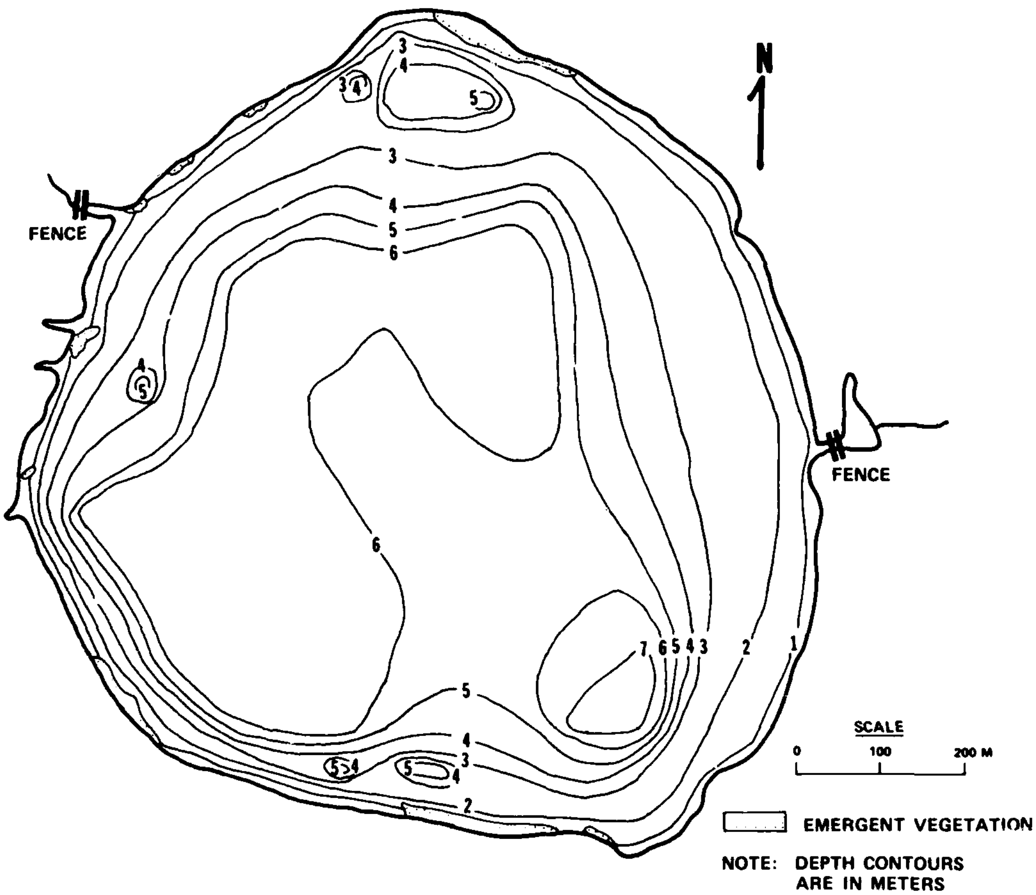


Figure 1. Bathymetric map of Lake Baldwin, Florida

Orange Lake

5. Orange Lake, a large shallow eutrophic lake located in Alachua and Marion Counties, Florida, is 9.2 km in length and 3.9 km in width, encompassing an area of 4900 ha (Figure 2). The maximum and mean depths are 4.9 and 2.9 m, respectively. Water level, however, fluctuates considerably from year to year and causes increases and decreases in surface area. Bottom composition is primarily deep muck.

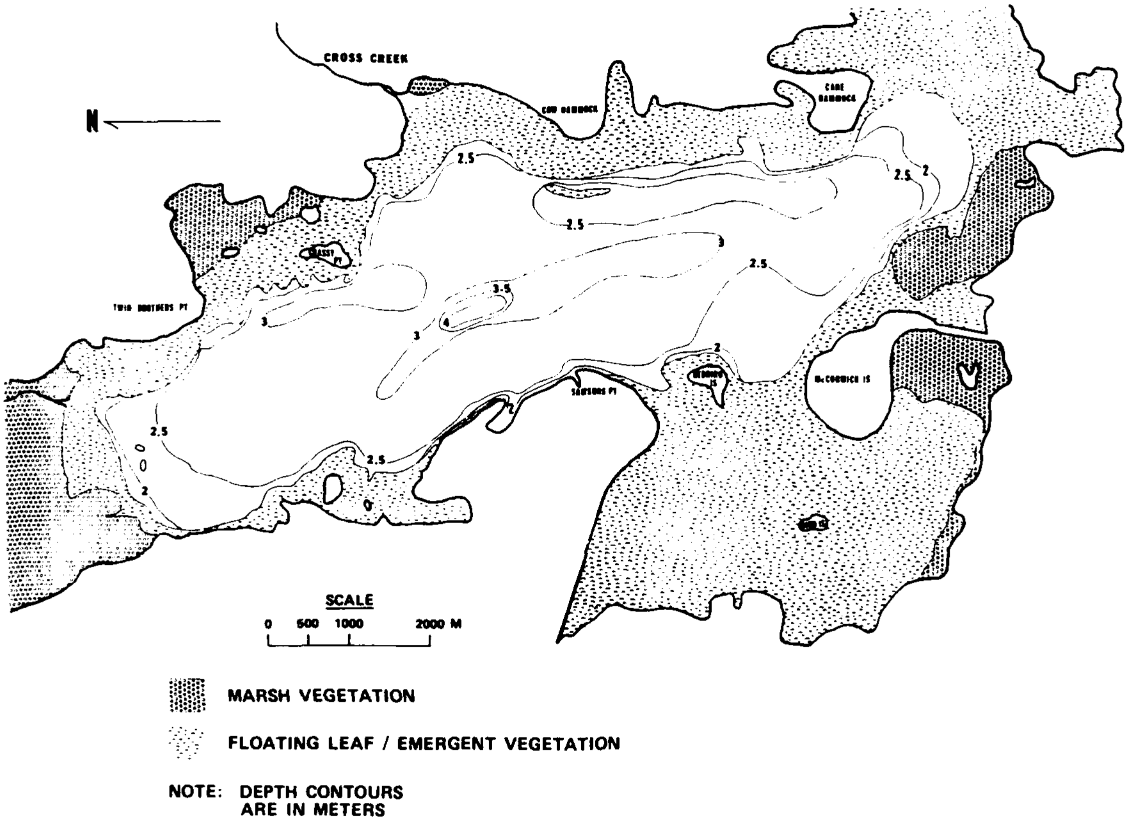


Figure 2. Bathymetric map of Orange Lake, Florida

6. Dense stands of littoral vegetation are prevalent within the lake. Spatterdock (*Nuphar* sp.) beds practically surround the lake and are interspersed with *Panicum, Ceratophyllum, Pontederia, Sagittaria*, and *Cabomba*. Before hydrilla introduction in 1974, the open water profundal zone was approximately 2000 ha.

Lake Pearl

7. Lake Pearl is a 25-ha lake located in Orange County, Florida (Figure 3). The lake has a maximum depth of 7.2 m and a mean depth of

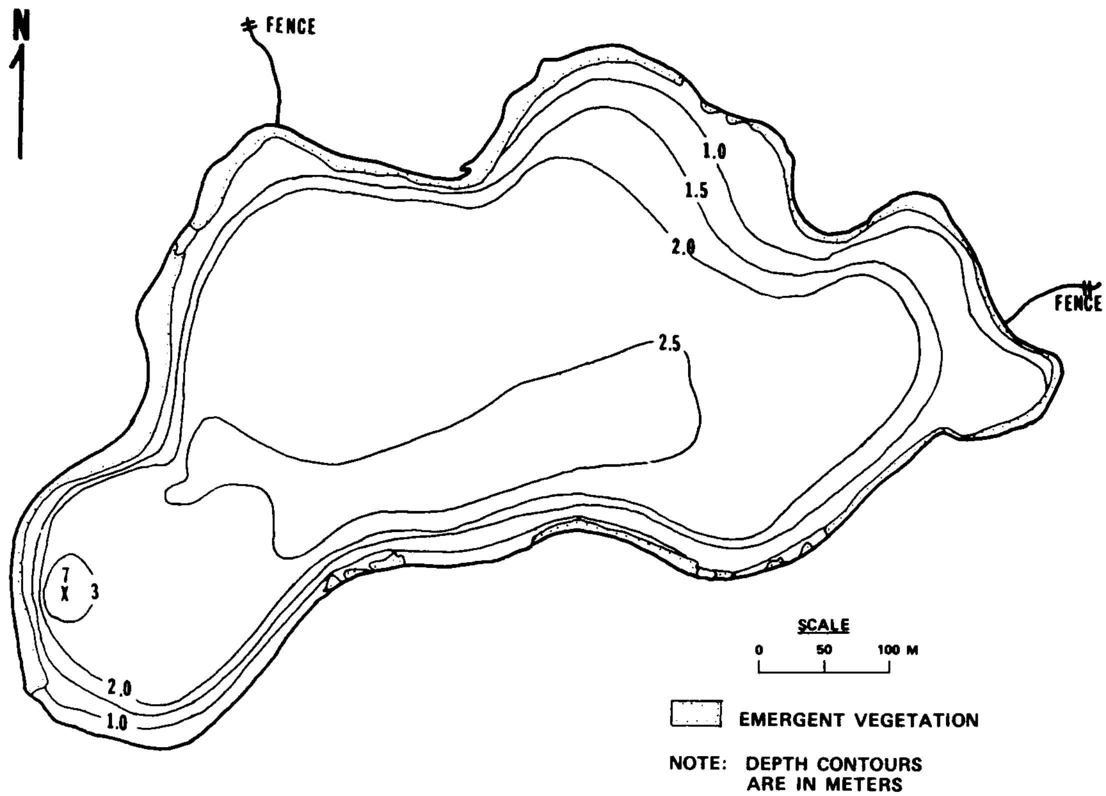


Figure 3. Bathymetric map of Lake Pearl, Florida

1.9 m. The submersed vegetation community is dominated by hydrilla with some bladderwort (*Utricularia sublata* and *U. inflata*) interspersed with the hydrilla. The floating leaved plants, *Nuphar advena* and *Nymphaea odorata*, cover approximately 15 percent of the lake's surface area. The lake is fringed by a band of *Scleria* and the bottom is composed primarily of muck.

Materials and Methods

8. A DE-719 Precision Survey Fathometer (Raytheon Marine Co., Manchester, N.H.) was utilized for all vegetation surveys. Procedures for conducting transects and determining quantitative vegetation parameters were followed according to the methods of Macéina and Shireman (1980). In Lake Baldwin, 14 transects totaling 11.32 km in distance were conducted quarterly starting in June 1979 (Figure 4). Thirteen

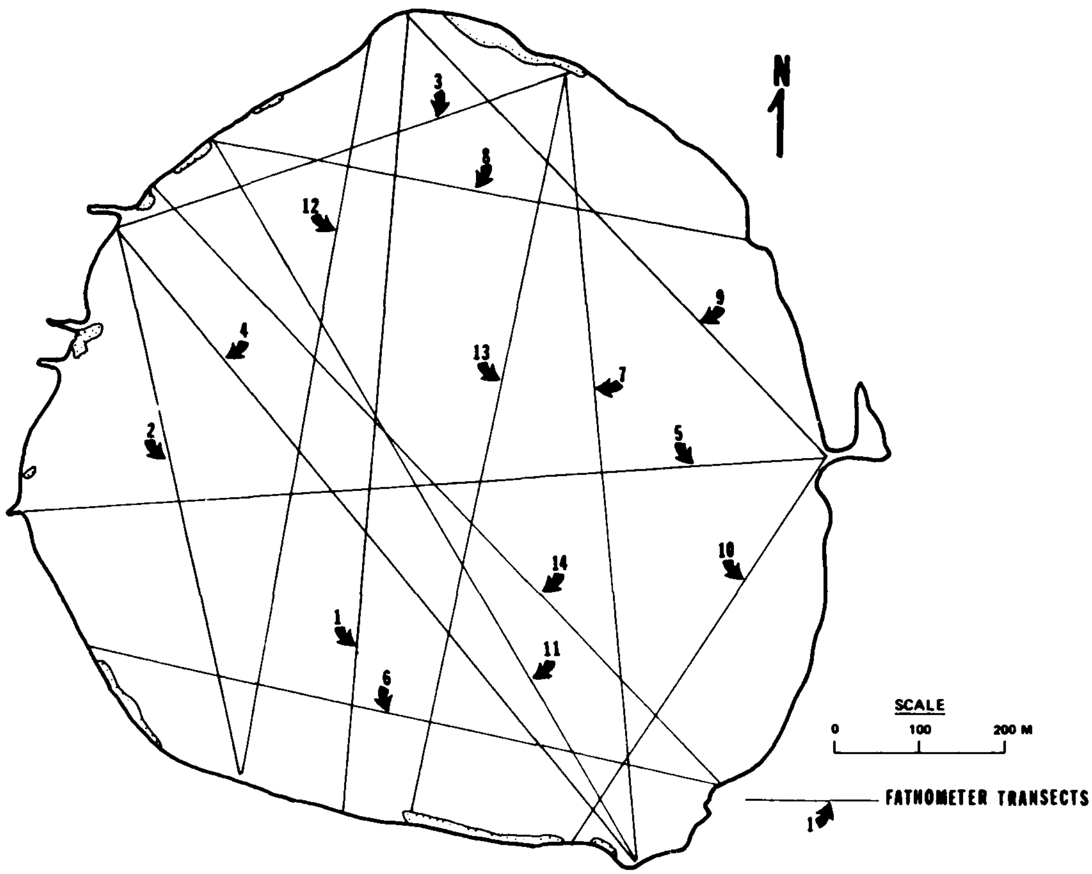


Figure 4. Transects conducted on Lake Baldwin with a recording fathometer

transects covering 12.96 km in distance were conducted on Orange Lake in January and June 1980 (Figure 5). Due to extensive surface matting, transects on Orange Lake were successfully conducted in an airboat. A bracket was mounted to the transom of the airboat to house the transducer. In Lake Pearl, 12 transects, 3.55 km in distance, were completed in March, May, and June of 1980 (Figure 6).

9. Attempts were made in Lake Pearl and Orange Lake to correlate and develop regression models predicting hydrilla biomass by fathometer tracing characteristics. On 10 March 1980, while transects were being conducted on Lake Pearl, numbered buoys were dropped to mark hydrilla biomass sampling stations. Simultaneously, corresponding fix marks were placed on the chart paper and the buoy number was recorded on the paper.

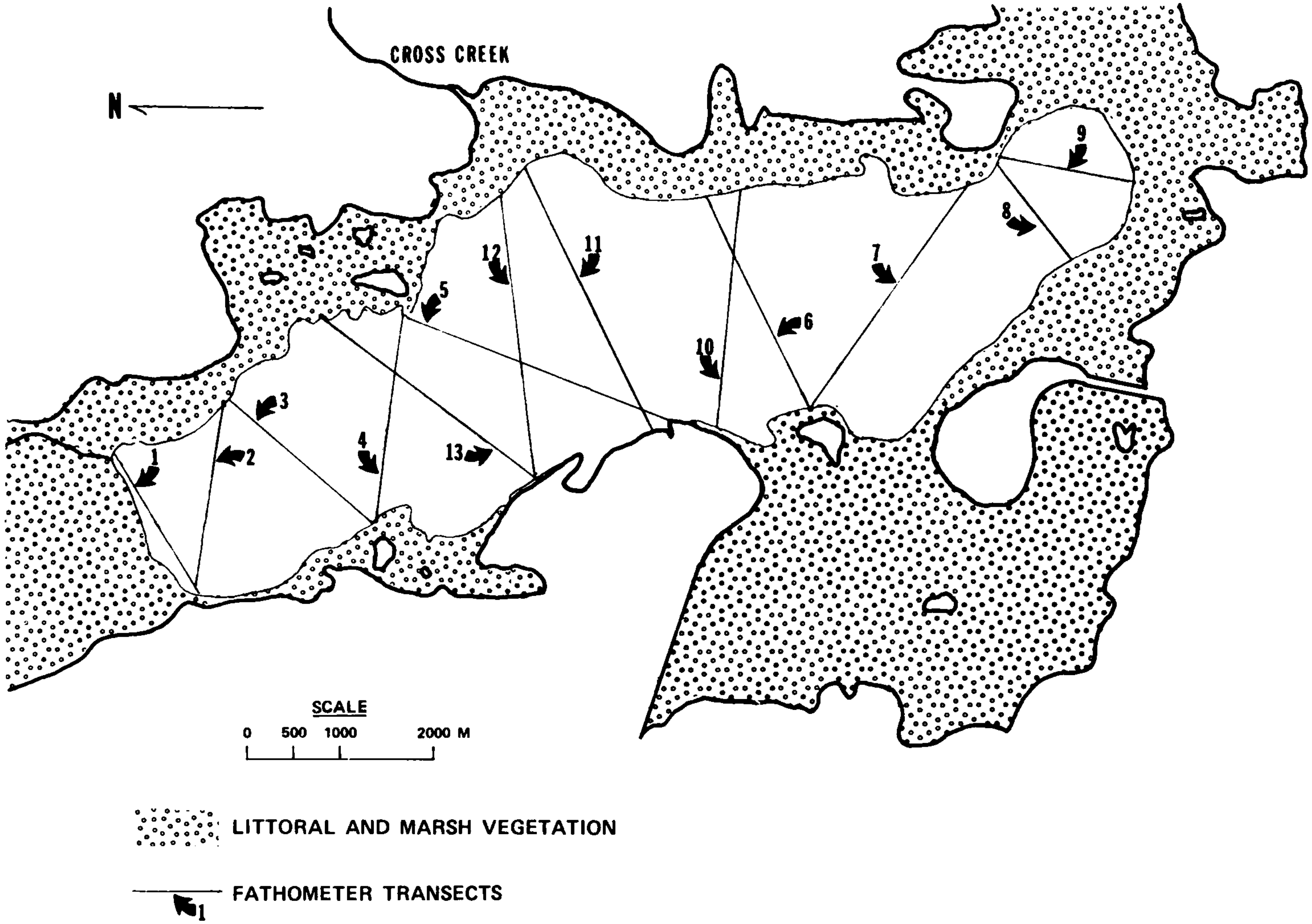


Figure 5. Transects conducted on Orange Lake with a recording fathometer

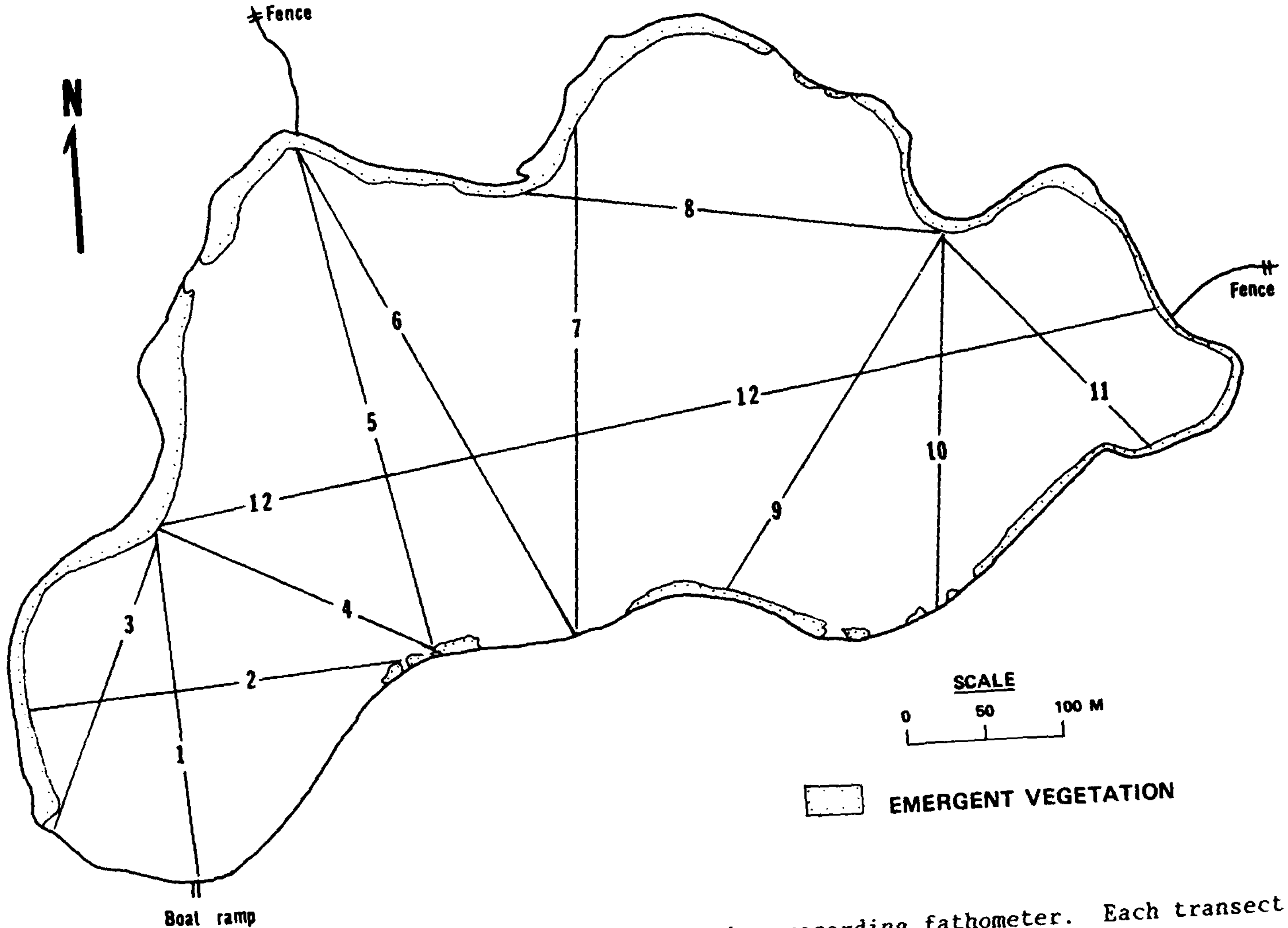


Figure 6. Transects conducted on Lake Pearl with a recording fathometer. Each transect was worked during the months of March, May, and June 1980

The following day, a circular core biomass vegetation sampler was used to take replicate 0.257-m^2 samples at each buoy. Samples collected with the biomass sampler were washed and shaken in a nylon net to remove excess sand, muck, and water and weighed to the nearest 5 g. Wet weights were later converted to kilograms per square metre for analysis. A total of 50 samples were taken from 25 stations and collected from water depths ranging from 1.5 to 2.6 m.

10. Utilizing sampling methods similar to those used in Lake Pearl, 32 hydrilla stations were established on two transects in Orange Lake on 19 May 1980. Single biomass samples were taken at each station in water depths ranging from 1.7 to 2.7 m.

Results

Orange Lake submersed macrophytes

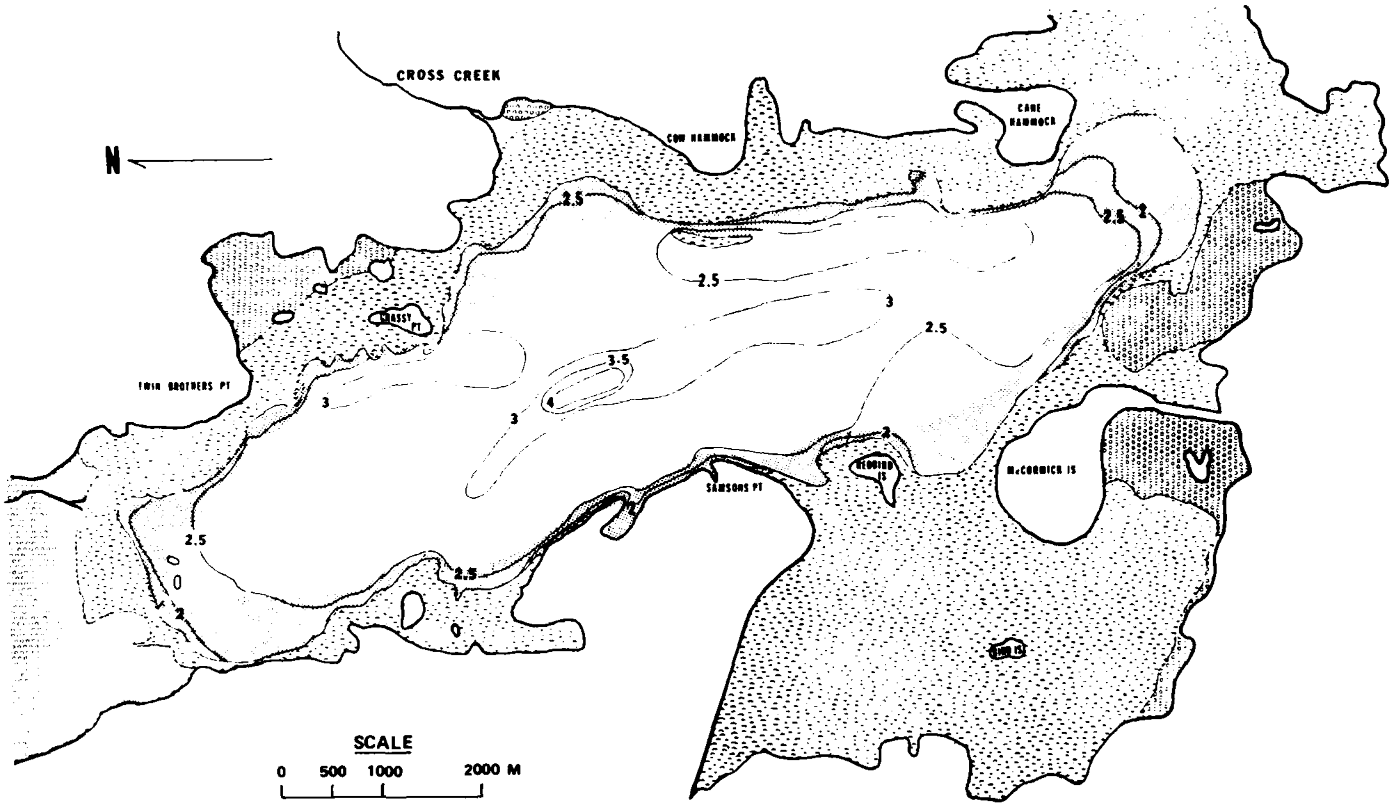
11. In Orange Lake, hydrilla distribution was surveyed in the deepwater area of the lake, beyond the *Nuphar* and *Panicum* communities. Before the introduction of hydrilla, this portion of the lake was generally free of submersed macrophytes. In January 1980, fathometer tracings indicated hydrilla infested 638 ha or 32 percent of this 1974-ha zone (Figure 7). By June, coverage increased to 34 percent (Figure 8). These hydrilla coverage values do not represent total hydrilla biomass in Orange Lake as hydrilla and a wide variety of other submersed macrophytes inhabit the floating leaved emergent zone in the lake.

Lake Pearl submersed macrophytes

12. Biomass sampling conducted on Lake Pearl revealed greater than 99 percent of the submersed macrophytes standing crop was composed of hydrilla. Bladderwort was found growing with hydrilla. Total lake volume was calculated to be 47.3 ha-m,* of which 1.1 ha-m was occupied by emergent vegetation (Figure 9). In March 1980, hydrilla infested 69 percent of the total water volume, declined to 47 percent by May, but then increased to 67 percent by June 1980 (Table 1). Herbicide application and

---

* 1 ha-m represents a total volume of 1 ha surface area, 1 m deep.



MARSH VEGETATION

FLOATING LEAF / EMERGENT VEGETATION

HYDRILLA

NOTE: DEPTH CONTOURS ARE IN METERS

Figure 7. Vegetation map of Orange Lake for January 1980

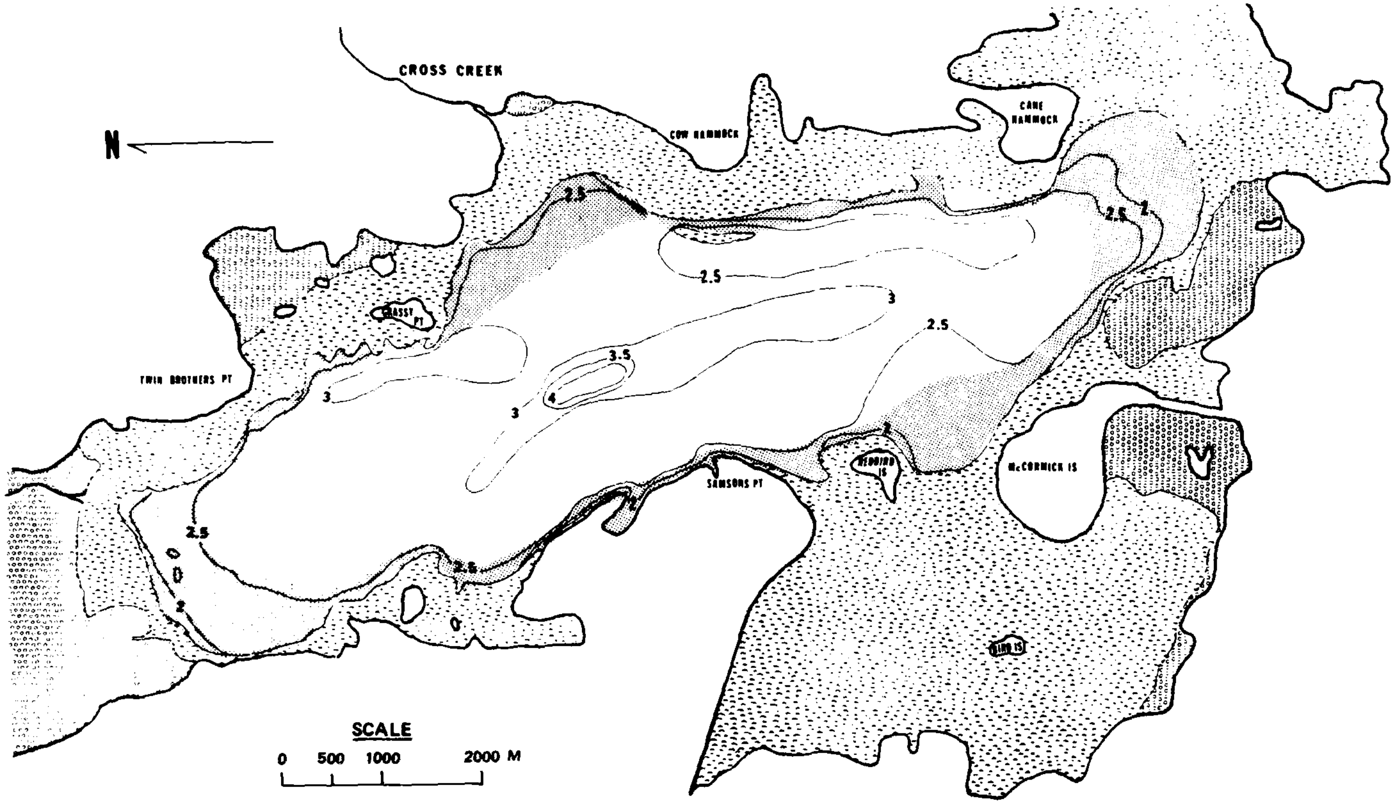


Figure 8. Vegetation map of Orange Lake for June 1980

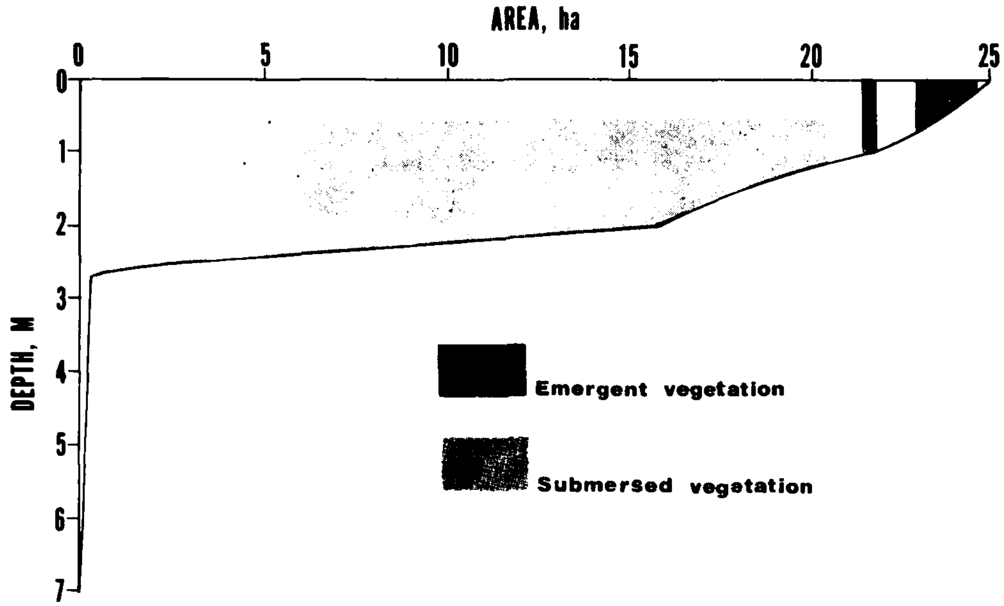


Figure 9. Submersed vegetation volume (hypsographic curve) for Lake Pearl, March 1980

winter dieback probably accounted for the decline observed in May 1980 in Lake Pearl. Coverage exceeded 92 percent in Lake Pearl during this time.

Hydrilla biomass-
<u>fathometer tracing correlations</u>

13. Biomass-fathometer data collected from Lake Pearl and Orange Lake in March and May 1980 were analyzed to correlate actual hydrilla biomass with fathometer tracing characteristics. Regression equations were constructed in a similar fashion to those utilized in Lake Baldwin (Macéina and Shireman 1980). Two separate considerations were employed to predict biomass: (a) thick hydrilla, indicated by sampling stations where dense hydrilla did not permit a reading of the lake bottom; and (b) sparse hydrilla, which permitted a clear reading to the bottom. Of the 25 stations sampled for hydrilla biomass in Lake Pearl, 22 were characterized by thick hydrilla. For this reason, sparse hydrilla models were not calculated in Lake Pearl. In Orange Lake, sampling stations were characterized by both sparse and thick hydrilla. Criteria

established for selecting best-fitting regression equations were maximizations of coefficients of determination (r^2).

14. Regression equations predicting hydrilla biomass with tracing characteristics for Lakes Pearl and Orange were all significant ($P < 0.05$) (Table 2). However, Orange Lake models displayed much higher correlation coefficients (r) than Pearl models. Correlation coefficients were lower than those calculated from Lake Baldwin. Two factors probably account for this: (a) a greater number of biomass samples were taken in Lake Baldwin and (b) the differences between the minimum and maximum water depths sampled in Lakes Pearl and Orange were not as great as those sampled in Lake Baldwin; therefore, tracing characteristics showing hydrilla abundance were much more homogeneous in these two lakes.

15. A difference in best-fitting regression lines was observed among the three lakes (Table 2). These differences may have been due to the shallower biomass samples taken in Lakes Pearl and Orange which altered the statistical relationships that fit the Lake Baldwin data. Hydrilla densities may have been different in these lakes, but the tracings obtained with the fathometer did not reflect these densities.

16. Best-fitting regression equations formulated for Lake Baldwin did not appear applicable to Lakes Pearl and Orange. A negative relationship between hydrilla height (HYDHT) and biomass ($b_1 = -2.797$) existed for the Lake Pearl thick hydrilla equations. As hydrilla height increases, biomass also should increase creating a positive slope (Macéina and Shireman 1980). A positive relationship between the distance from the top of the hydrilla plant to the water surface (HYDSUR) and biomass ($b_2 = +1.085$) was noted for the Orange Lake sparse hydrilla equations. This also contradicts earlier findings from Lake Baldwin, where a negative relationship existed. As hydrilla declines in height from the water, surface biomass should decrease.

17. The independent variables that best predicted hydrilla biomass in Lake Baldwin were used to calculate Orange Lake sparse and thick hydrilla (Table 3). Correlation coefficients were slightly less than those calculated for Orange Lake. However, regressions calculating the sums of squares declined when Lake Baldwin variables were used for Orange

Lake data, causing respective F values to decline and predictions to become less valuable. Intercepts and independent slope coefficients were different from those found in Lake Baldwin. Slope coefficients for hydrilla height and cover were positive in Orange Lake models. A negative relationship for the hydrilla surface distance was observed in the thick hydrilla similar to the relationship found in Lake Baldwin. A positive slope between hydrilla surface distance and biomass existed in the Orange Lake sparse data, unlike the situation in Lake Baldwin.

18. The best-fitting Lake Pearl thick hydrilla model demonstrated that the same independent variables as those used in Lake Baldwin were the best variables to predict thick hydrilla biomass in Lake Pearl. The slope coefficients predicting biomass from the log (hydrilla surface) were similar, -1.328 and -1.301, but the equation intercepts and hydrilla height slope values were not equal in both lakes.

19. In order to analyze response differences among Lakes Baldwin, Orange, and Pearl, the compartments of the thick and sparse hydrilla equations were used to form multiple linear regressions. Equations were calculated by regressing independent variables (HYDHT, COVER, HYDSUR) against biomass.

20. Thick hydrilla height slopes for Lakes Orange and Baldwin were found to be similar ($P > 0.05$, Figure 10); however, intercepts were significantly ($P < 0.01$) different. Similar slopes indicated that a change in hydrilla height produced an equal change in biomass for both lakes. The higher intercept calculated for Orange Lake indicated that hydrilla biomass per unit length of hydrilla height was greater in Orange Lake. The Lake Pearl hydrilla height-biomass relationship was not analyzed because a negative and highly insignificant regression slope was calculated. The hydrilla surface distance equations for the Baldwin, Orange, and Pearl thick hydrilla models demonstrated significant ($P < 0.05$) differences in slope (Figure 11), revealing different magnitudes of biomass change in the three lakes, with Orange Lake data producing the steepest slope and Lake Pearl the flatest.

21. When comparing sparse hydrilla independent variables from Lakes Baldwin and Orange, water depths greater than 2.7 m in Baldwin

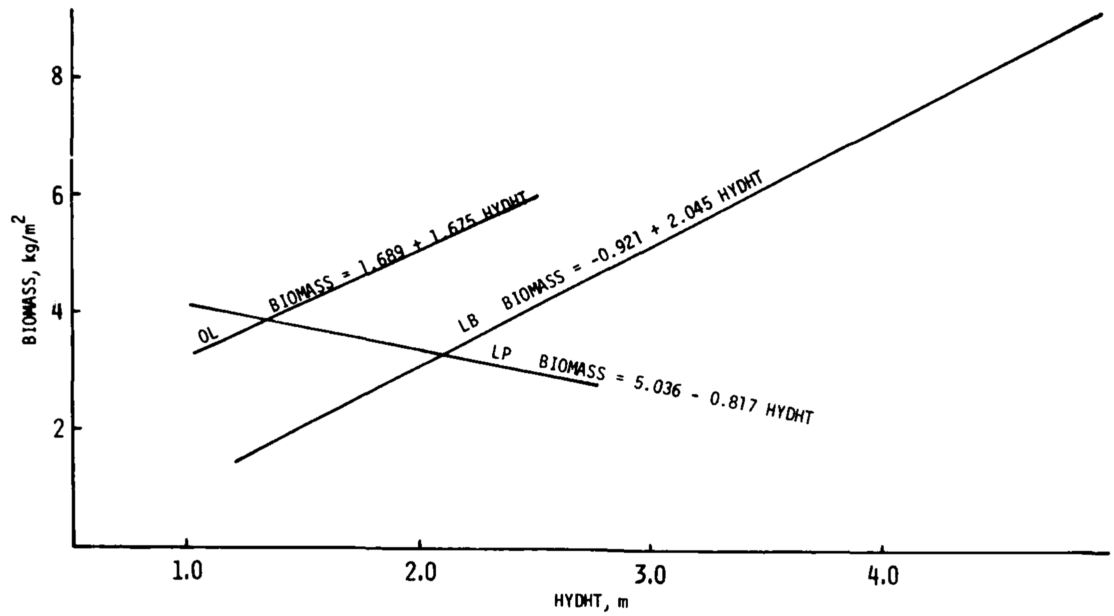


Figure 10. Hydrilla height slopes (thick hydrilla) for Lake Baldwin (LB), Lake Pearl (LP), and Orange Lake (OL) Florida

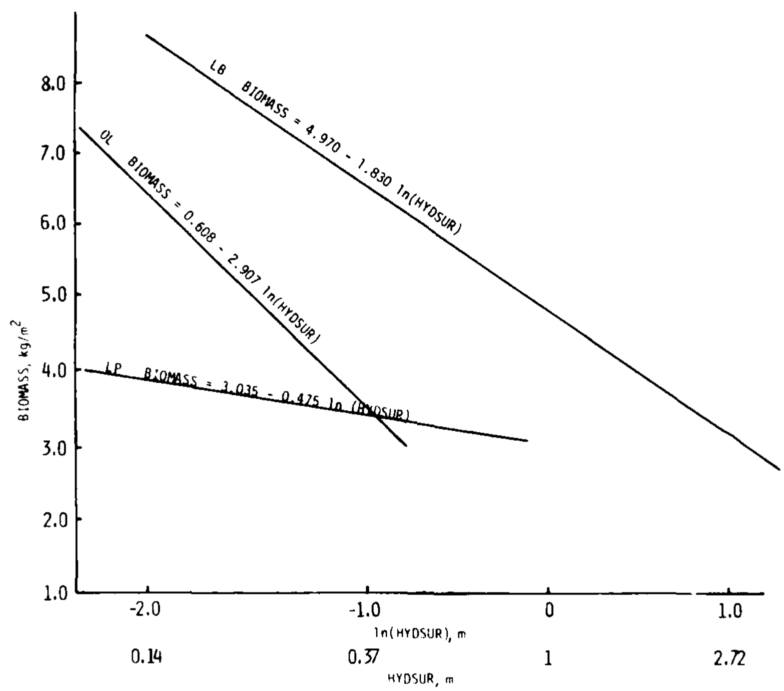


Figure 11. Hydrilla surface slope relationships for Lake Baldwin (LB), Lake Pearl (LP), and Orange Lake (OL)

were eliminated from the regression equations. This eliminated the variation caused by deepwater hydrilla. Hydrilla height and hydrilla surface equations demonstrated respective positive and negative slopes not significantly different ($P > 0.05$) in Lakes Baldwin and Orange (Figures 12 and 13). Corresponding intercepts in Lake Baldwin were significantly higher ($P < 0.01$) for both equations than those in Orange Lake, which indicated greater biomass values in Lake Baldwin. Regressing biomass against percent vertical cover produced slopes where the cover values between the two lakes did not overlap (Figure 14). Cover values for shallow water sparse hydrilla were above 50 percent in Lake Baldwin, while cover values were generally below 50 percent in Orange Lake. Slope analysis, however, revealed a significant ($P < 0.05$) difference in cover slopes between the two lakes.

22. Data from Lakes Baldwin, Orange, and Pearl indicate that the independent predictive values of biomass taken with the fathometer did not form similar relationships in each lake. Differences in subsurface light intensity, water chemistry, and substrate types may have caused differences in hydrilla growth patterns that were not detectable. Differences in the number of stems per unit area and mean internodal lengths could have altered biomass estimates among lakes. Two independent variables predicting hydrilla biomass in these three lakes, hydrilla-height and the hydrilla-surface distance, do not consider hydrilla density (i.e., hydrilla weight/m^3, number of stems/m^3, $\bar{X}$ internodal length/m^3). These two variables were used in the sparse and thick hydrilla equations and therefore do not explain the biomass variation in different hydrilla densities. For the sparse hydrilla equations, vertical percent cover may be sensitive to a change in hydrilla density, hence biomass. Orange Lake hydrilla demonstrated lower vertical percent cover values than Lake Baldwin hydrilla; therefore, the corresponding biomass values were lower (Figure 14). The influence of hydrilla height and hydrilla surface variables, however, might be partially negating the predictive capability of the cover variable in the Orange Lake multiple regression.

23. Thick hydrilla relationships utilized only hydrilla height

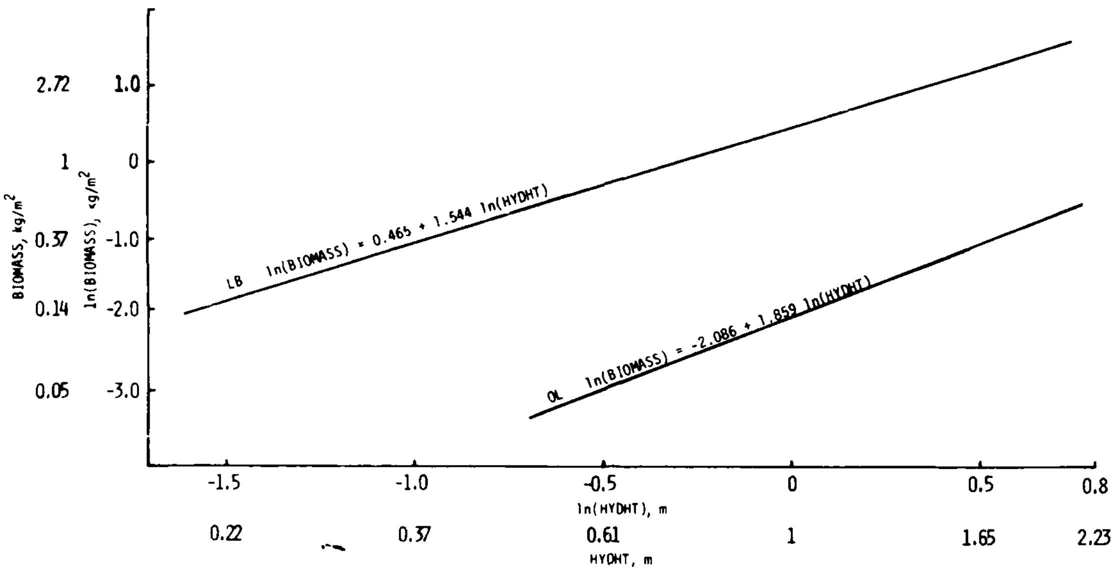


Figure 12. The independent variable HYDHT regressed against biomass illustrating Orange Lake and Lake Baldwin sparse hydrilla

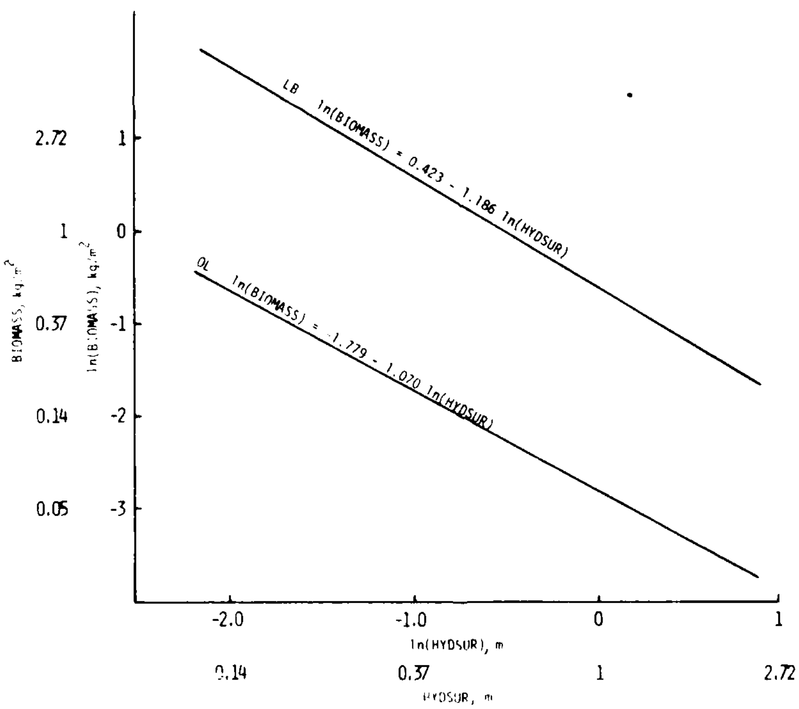


Figure 13. The independent variable HYDSUR regressed against biomass illustrating Orange Lake and Lake Baldwin sparse hydrilla

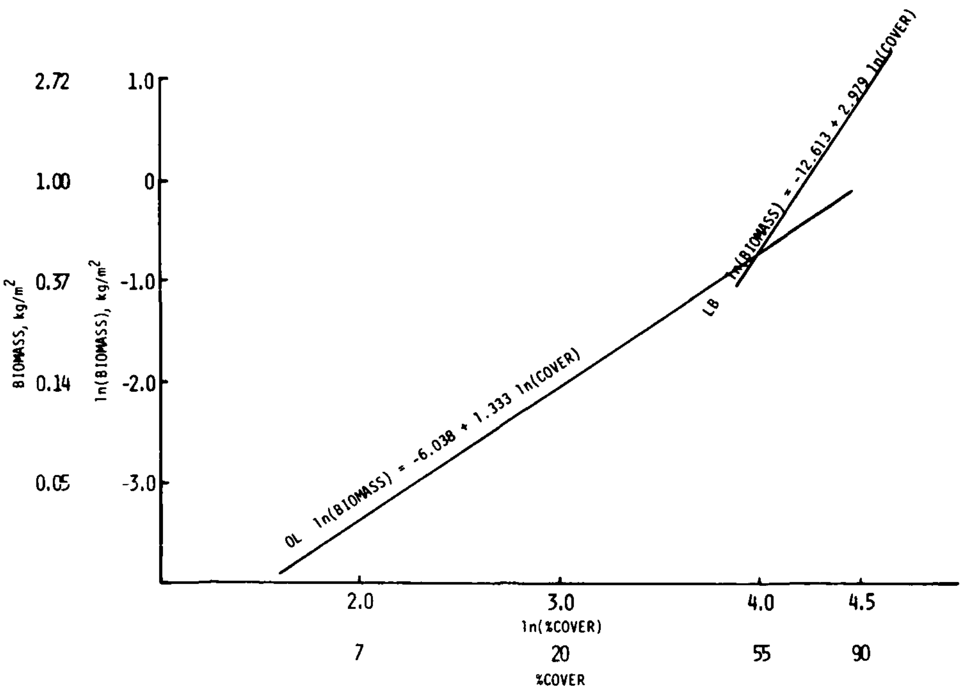


Figure 14. The independent variable COVER regressed against biomass illustrating Orange Lake and Lake Baldwin sparse hydrilla

and hydrilla surface distance to predict biomass in Lakes Baldwin, Orange, and Pearl; therefore, plant density was not considered in this type. One variable not entered into the current thick consideration, hydrilla thickness, was analyzed in the three lakes as a measure of hydrilla density. Hydrilla thickness was defined as the distance from the top of the hydrilla plant to the bottom of the visible tracing pattern (Figure 15). Hydrilla was certainly growing below this point down to the hydrosoil, but plant density prevented sound-wave transmission. A negative relationship between hydrilla thickness and biomass was sought; i.e., as the hydrilla thickness decreases, plant density and biomass should increase. However, analysis proved this factor to be insignificant; hence, it was not included in the model.

24. Actual biomass data indicate that hydrilla density differences do occur between lakes (Table 4). Thick hydrilla growing in 2 to 3 m of water in Lake Baldwin had higher weight-volume values than similar hydrilla in Orange Lake, and was significantly ($P < 0.05$) higher

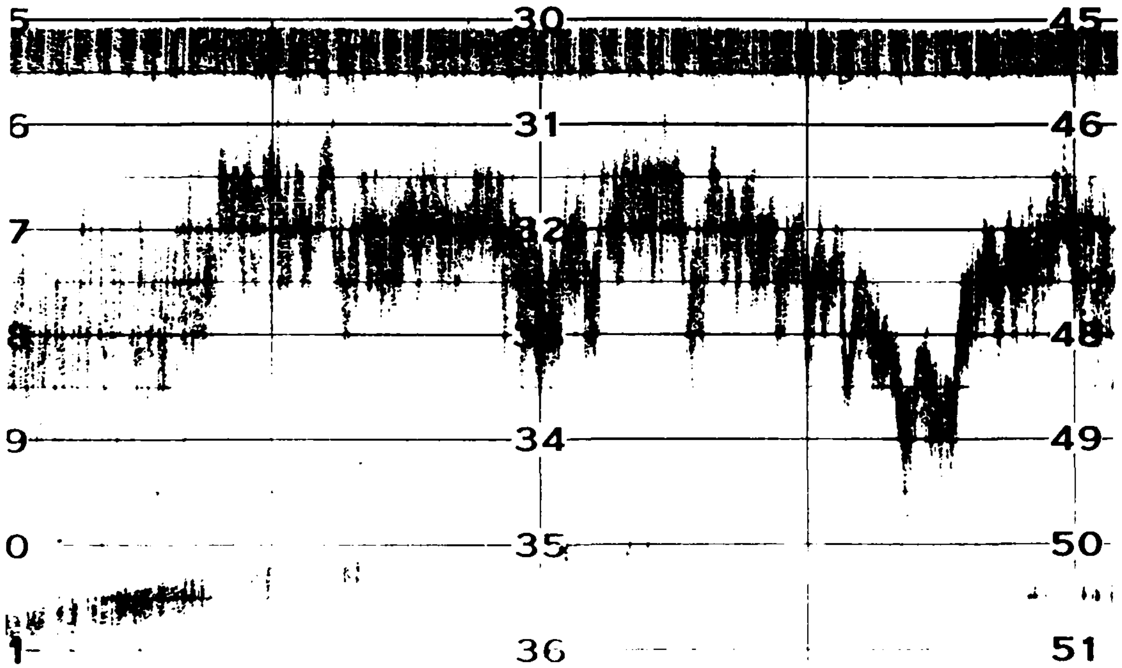


Figure 15. Section of fathometer chart tracing from Lake Baldwin depicting thick hydrilla

than values obtained from Lake Pearl. The biomass-hydrilla surface distance relationship among the three lakes clearly shows, for the ranges of samples collected, that Lake Baldwin had the highest equation response followed by Lakes Orange and Pearl. This coincides with the weight-volume values calculated.

25. Sparse hydrilla weight-volume values for the 2- to 3-m depth interval showed Lake Baldwin values three times greater than Orange Lake values (Table 4). Again, equations plotting hydrilla height, hydrilla surface, and cover against biomass show Lake Baldwin to have a higher response (intercepts and slope), hence biomass, than that in Orange Lake (Figures 12-14).

26. Plant density variation may be due to differences in light reaching the plant and/or nutrients. Higher weight-volume hydrilla values observed from Lake Baldwin coincide with a greater light compensation point (5 to 6 m) and higher total water hardness (102 to 110 mg/ℓ) than those found in Lakes Orange and Pearl. The light compensation

point was generally below 2 m in both these lakes and total water hardness ranged between 23 and 61 mg/ℓ. Generally, higher water hardness ($CaCO_3$) in lakes allows a greater amount of carbon to be available to macrophyte photosynthesis due to the availability of biocarbonate and, depending on pH, carbonate ions. Recent biomass-fathometer samples collected in Crystal River, Florida, a spring-fed river, indicate hydrilla biomass and density to be very high. Light and total water hardness values in the Crystal River typically exceed those in Lake Baldwin.

27. In Lake Baldwin, percent vertical cover, which may be sensitive to hydrilla density, was found to be the strongest of the three variables predicting sparse hydrilla (Macéina and Shireman 1980). Further investigations need to be conducted to determine the relationship of plant density to various depth intervals and different bodies of water.

PART II: LAKE BALDWIN FISHERIES AND PLANT DISTRIBUTION STUDY

Introduction

28. Currently, white amur are being intensively investigated as a biocontrol agent of nuisance aquatic plants. The ability of white amur to consume and control submersed plants is well recognized. The positive or negative environmental impact of the fish in lakes is still under debate (Shireman 1979).

29. Lake Baldwin was originally stocked in 1975 with 5000 fingerling white amur. The chemical herbicide Hydout [Mono (N, N-dimethylalkylamine)] was also applied to the lake to eliminate hydrilla. By the summer of 1977, hydrilla once again became a problem in the lake with coverage estimated to be 50 percent. In order to determine if sufficient white amur were present for hydrilla control, the lake was selectively treated with rotenone (Colle et al. 1978). The estimated number of white amur remaining in the lake was approximately 3 fish/ha. An additional 1845 white amur over 304 mm in total length (TL) were stocked during the summer of 1978. These fish were large enough to avoid predation (Shireman, Colle, and Rottmann 1978). Hydrilla was monitored during 1978 and coverage approached 80 percent by fall. The fish, however, had not been stocked for sufficient time to influence hydrilla density.

30. The purpose of this research project was to continue monitoring hydrilla abundance-white amur interactions in Lake Baldwin.

Objectives

31. The objectives were as follows:

- a. To continue vegetation transects utilizing a recording fathometer in Lake Baldwin to determine hydrilla biomass and coverage.
- b. To monitor white amur growth and impact on hydrilla, and evaluate white amur recapture techniques.

c. To continue sport fish population investigations to determine the effects of hydrilla and/or white amur on the lake ecosystem.

Materials and Methods

32. A DE-719 Precision Survey Fathometer (Raytheon Marine Co., Manchester, N.H.) was utilized for all vegetation surveys. Procedures for conducting transects and determining quantitative vegetation parameters were followed according to the methods of Macéina and Shireman (1980). In Lake Baldwin, 14 transects totaling 11.32 km in distance were conducted quarterly starting in June 1979 (Figure 4).

33. White amur were captured utilizing direct current pulse electroshock fishing gear, monofilament gill nets, rotenone, and a modified gill net-haul seine in Lake Baldwin. Fish were measured in millimetres for total length and weighed to the nearest 0.05 kg. Largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and redear (*Lepomis microlophus*) were collected with electroshocking gear in January and June 1980 for condition factors and length frequency data. Condition factors were calculated from the following formula:

$$K_{(TL)} = \text{Weight (g)} \times 100{,}000/(TL)^3 \qquad (1)$$

Three 0.081-ha block nets were set in Lake Baldwin in September 1979. These areas were treated with 2.0 mg/ℓ of rotenone (5 percent active ingredient Noxfish). All fish inside the nets were collected, separated into 40-mm size groups (0 to 40 mm, 41 to 80 mm, etc.), counted, and weighed to the nearest gram.

Results

Hydrilla volume

34. The volume of hydrilla infesting a water body was derived utilizing a hypsographic curve, which is a plot of mean hydrilla height and area infestation by depth intervals (Figure 16). Total lake volume was a summation of the volume of water present in every depth contour;

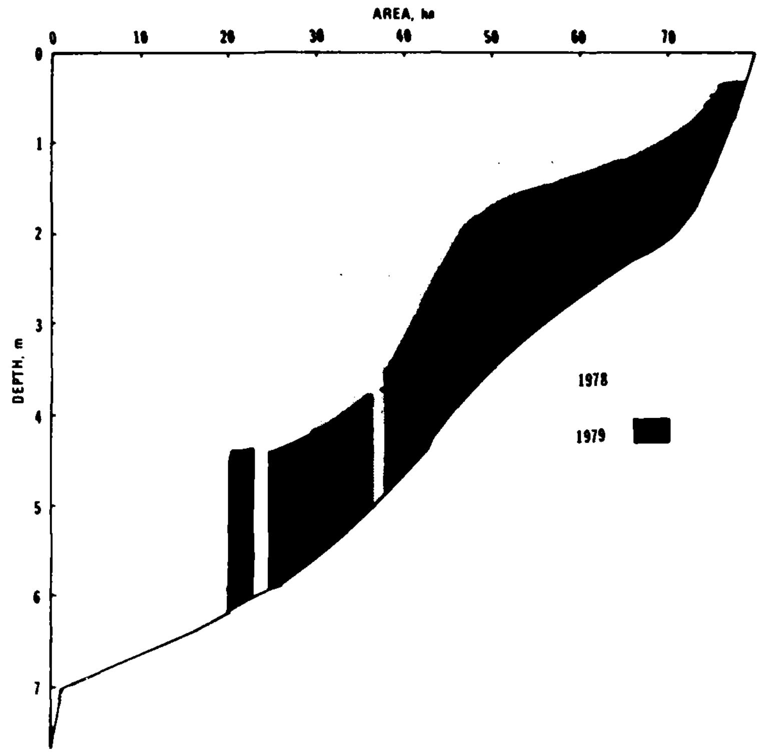


Figure 16. Hydrilla volume (hypsographic curve) of Lake Baldwin for June 1978 and June 1979

the area of each contour was determined by planimetry (Wetzel 1975). Mean hydrilla height values were plotted on hypsographic volume curves at the mean depth calculated for each depth interval. The percentage of depth interval areas infested with hydrilla was considered and incorporated in each hypsographic figure. A line was drawn connecting the points designating the top of the hydrilla plants along the depth intervals. The enclosed area from the top of the plants to the lake bottom represents the in situ volume of water occupied by hydrilla in the lake. Hydrilla volume was calculated by planimetry and the percentage of the lake volume infested with hydrilla was derived by dividing hydrilla volume by lake volume. An example of the data utilized to construct Figure 16 for Lake Baldwin is presented in Table 5.

35. The total water volume of Lake Baldwin was calculated to be 344.5 ha-m. The hydrilla volume in the lake declined from 106.9 ha-m to 69.8 ha-m or from 31 to 21 percent of the total lake volume between June

1978 and June 1979 (Figure 16). Total percent cover or the area of the lake infested with hydrilla did not decline, but increased from 62 to 69 percent during the same period. The discrepancy between the two measurements was caused by a decrease in hydrilla height, especially in water depths greater than 4 m. Decreased plant height, therefore, caused a decrease in hydrilla volume. The total volume of hydrilla in a lake is a better descriptive quantitative parameter than percent cover since area coverage (hectares) as well as vertical coverage is considered.

36. The percentage of the total water volume in Lake Baldwin infested with hydrilla increased from 31 percent in June to 41 percent by November 1978, then declined during 1979 (Table 6). Winter dieback and white amur consumption of hydrilla were believed to have caused the decline in 1979.

Interrelationship between total percent cover, hydrilla volume, and standing crop

37. An increase in hydrilla was noted during the summer and fall months of 1978 followed by a decline in the winter and spring of 1979 (Figure 17). Transect percent cover and total percent cover data indicated peak abundance in November 1978 and January 1979. Total hydrilla standing crop, hydrilla height, and hydrilla surface data indicated that peak abundance occurred in August 1978 whereas volume data demonstrated peak abundance in November 1978.

38. The increase in total percent cover during November 1978 and January 1979 was due to the expansion of sparse hydrilla into the 6.0- to 6.9-m depth strata after August 1978. However, hydrilla growing at this depth interval contributed less than 5 percent to the total standing crop for November 1978 and January 1979. Although total percent cover was less in August than in November 1978, the maximum standing crop value obtained in August was due to extensive surface matting and peak hydrilla height values. Hydrilla volume calculations were generated from both area infestation and hydrilla height data. The increase in total percent cover from August to November 1978 from 67 to 78 percent caused a slight increase in percent hydrilla volume, from 39 to

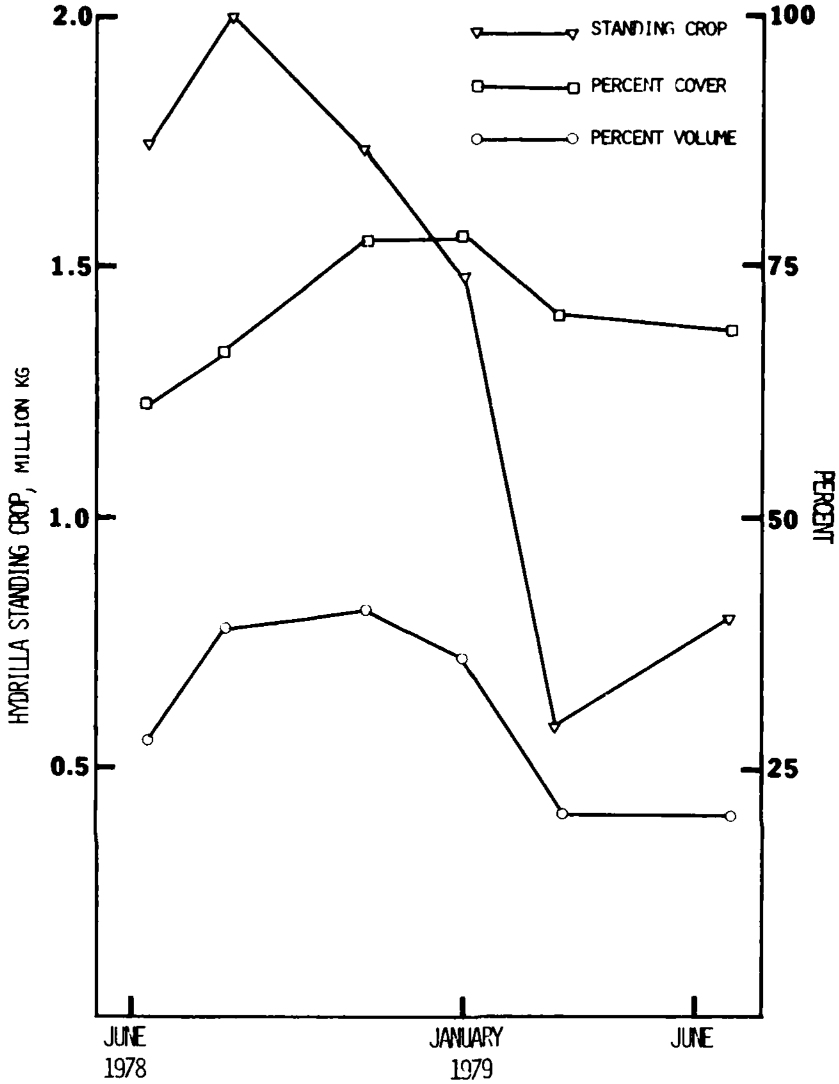


Figure 17. Hydrilla standing crop, percent cover, and percent volume from Lake Baldwin, June 1978 to June 1979

41 percent, even though hydrilla height declined in water depths less than 5 m during this time.

39. Hydrilla volume estimates remained constant (21 percent) in March and June 1979, but standing crop estimates indicated an increase of 0.2 million kg during this time. Hydrilla growth characteristics differ in shallow and deep water which might explain these differences. As

the plant approaches the water surface the following occurs: (a) the amount of sunlight reaching hydrilla increases and more nodes are produced on the stem, and (b) the stem tends to grow and extend itself in a horizontal position to capture a greater proportion of the sunlight with thick, entangled, intertwined mats resulting. These two factors cause an increase in weight of hydrilla per unit volume when hydrilla is growing in shallow water or close to the surface.

40. Utilizing biomass data collected with a 0.257-m^2 core vegetation sampler, the weight of hydrilla per cubic metre was calculated by dividing actual biomass by hydrilla height obtained from chart tracings. For example, if actual biomass equaled 2 kg/m^2 and chart tracings indicated that hydrilla height was 2 m, the hydrilla weight per unit volume would equal 1.00 kg/m^3. Hydrilla weight per unit volume of water decreased with increasing water depth from 4.51 kg hydrilla/m^3 in the 1.0- to 1.9-m water depth to 0.06 kg hydrilla/m^3 in the 6.0- to 6.9-m water depth (Table 7). From March to June 1979, a dramatic decrease in hydrilla height occurred in water depths greater than 4 m. Thus, the major portion of hydrilla volume was located in shallow water. Actual hydrilla weight-volume data indicated that a greater standing crop of hydrilla existed in shallow water than in deep water on a volume basis. Therefore, standing crop estimates were different from volume estimates due to greater infestations in shallow water.

41. In analyzing results and changes in hydrilla biomass, the calculation of a variety of quantitative vegetation parameters is recommended.

Submersed vegetation

42. Hydrilla disappeared in Lake Baldwin by April 1980 and was replaced by the benthic filamentous algae *Lyngbya* sp. (Table 8). Coverage dropped from 69 percent hydrilla in June 1979 to less than 5 percent *Lyngbya* by September 1980. Similarly, percent volume and standing crop data revealed a drastic reduction in hydrilla abundance in the lake. White amur consumption and a phytoplankton bloom which appeared in April 1979 were believed to have caused the elimination of hydrilla. Light compensation point (1 percent light transmittance) dropped from 5 to 6 m

during the summer of 1978 to less than 3.0 m during the summer of 1979 and throughout the remainder of the study period.

Phytoplankton

43. Algal investigations indicated that in June 1979 the lake supported a moderate blue-green bloom dominated by the colonial coccoid algae *Anacystis* and the uniseriate filamentous *Anabaena*. Blue-green dominance continued through September 1979 as concentration levels reached an apparent seasonal maximal of over 3.0×10^6 cells/ℓ (Figure 18). In December 1979, 70 percent of the genera were green and 30 percent were blue-green compared to 50 percent for each in June of 1979. Concentration levels decreased through the winter months. In April 1980, the lake supported a moderate bloom which was dominated by the green algae *Pediastrum*. Greens dominated the phytoplankton flora through September 1980 as concentration levels remained at 1.7 $\times 10^6$ cells/ℓ. Between the summers of 1979 and 1980 the phytoplankton flora shifted from one dominated by blue-green algae to green algae.

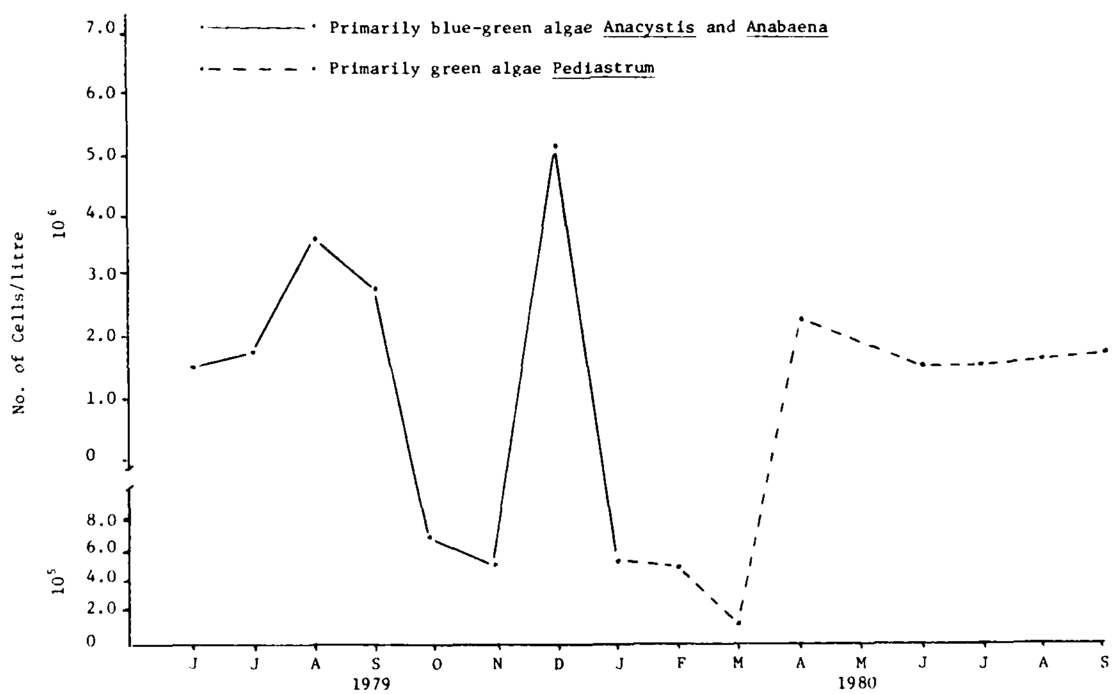


Figure 18. Number of algal cells per litre, Lake Baldwin, Florida, June 1979 through September 1980

During this same time period, hydrilla abundance declined from over 60 percent coverage to total elimination. An apparent increase or decrease in total algal cells per litre was not evident in Lake Baldwin in 1980 following control of hydrilla by the white amur.

White amur capture techniques

44. Between December 1978 and August 1980, a total of 268 white amur were captured from Lake Baldwin. Capture techniques included electroshocking, gill nets, rotenone, and a modified gill net-haul seine. White amur captured prior to January 1980 were released, except for gill net mortalities (about 5 percent). After this time, all fish were killed or removed due to the severe decline of hydrilla in the lake.

45. Electroshocking. A total of 29 white amur were captured during five sampling dates utilizing pulsed direct current (Table 9). Capture rates varied from 0.5 to 3.3 fish/hour with an overall mean of nearly 1 fish/hour. The majority of white amur captured were shocked at night although daytime and nighttime efforts were nearly equal. In Lake Baldwin, electroshocking of white amur proved to be a fair method for obtaining some fish for growth data. As a removal technique, however, electrofishing is time-consuming, costly, and requires at least two people. Also, only a small proportion of Lake Baldwin could be sampled since the shocking rig used was most effective in water depths less than 2.5 m, and 70 percent of Lake Baldwin is greater than 3 m in depth.

46. Gill netting. A total of 97 white amur were recovered during 1 year, utilizing monofilament gill nets in Lake Baldwin (Table 10). The most effective mesh size for white amur capture was 20.3-cm (8-in.) stretch mesh. Catch per effort was greatest between December 1979 and March 1980. Nets set over 2 to 3 m of water, and fished at the edge of a hydrilla bank or over hydrilla, were found to be most effective. Gill nets were also fished perpendicular, parallel, and diagonal to shore with no apparent differences in overall catchability. White amur were only caught at night with gill nets. Nets did not catch white amur during daylight hours in September and December of 1979; therefore, daytime sets were abandoned.

47. White amur sampling and removal utilizing gill nets proved to

be an effective capture technique in Lake Baldwin during the winter of 1979-1980. Gill nets can be set and picked up by one person and usually require only a few hours of attention. The large decline in catch per effort of white amur with gill nets during the summer of 1980 was probably caused by fish seeking cooler and deeper spots in the lake, avoiding shallow and warmer water, and/or the removal of hydrilla from the areas. Winter gill netting will be attempted again during 1980-1981; however, hydrilla will probably not be established in the lake at this time.

48. Rotenone. On the night of 10 April 1980, 3.19 ha of Lake Baldwin was secured employing 520 m of gill nets and 2-mm mesh block nets in an attempt to remove white amur from the lake (Figure 19). A

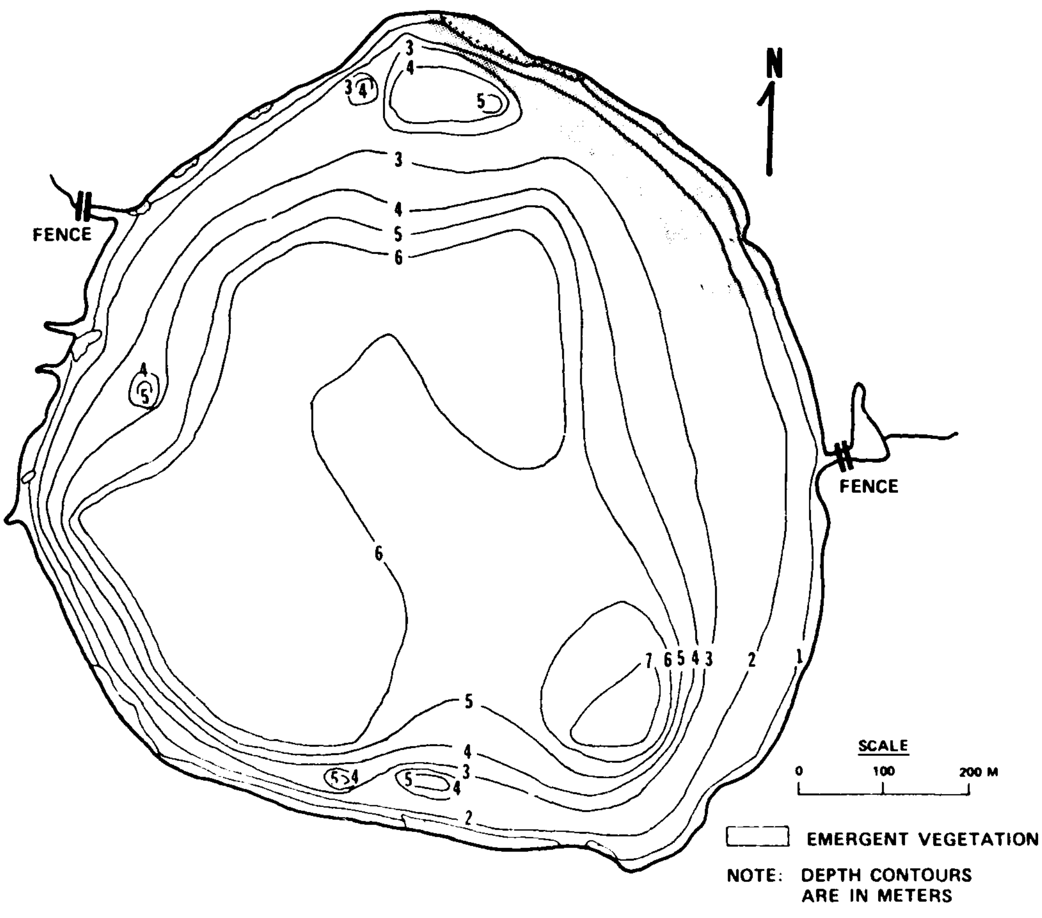


Figure 19. Shaded area in Lake Baldwin illustrating 3.19-ha rotenone treatment

0.18-g/ℓ rotenone concentration was applied evenly to the area and all white amur and largemouth bass greater than 250 mm in total length were recovered. Marking (1972), Colle et al. (1978), and Hardin (1980) reported concentrations of 0.05 to 0.10 mg/ℓ rotenone were lethal to white amur. Therefore, the rotenone treatment applied in Lake Baldwin was adequate to kill white amur.

49. Seventeen white amur, ranging in weight from 6.05 to 14.30 kg, were removed. Largemouth bass mortality was high with over 90 kg of fish killed (see later section). The operation was labor intensive, involving 4 boats and 10 workers, and proved to be marginally successful. The 3.19-ha treatment area was chosen because it was the most effective location for gill netting white amur in January and March 1980.

50. Modified gill net-haul seine. In early May 1980, a modified net designed by Woodard W. Miley II (Senior Biologist, Aquatic Plant Research Center, University of Florida, Gainesville, Fla.) was utilized to remove white amur from Lake Baldwin. The net, constructed of cotton with a float line and light lead line, was 366 m long and 6.1 m deep, and had a 1.8-m trammel net attached to the top float line. Mesh stretch on the net was 17.8 cm (7 in.). Personnel included 10 workers from the University of Florida, Florida Department of Natural Resources, Orange County Pollution Control Board, and the U. S. Department of the Navy. A SCUBA diver removed snags from the net. The most effective way of using the net was to purse the net out from shore and pull one side onto the beach.

51. Six hauls were made with only two white amur caught after 1 day of seining. Later, a school of white amur was seen close to shore in 4.5 to 6.5 m of water. The school was encircled and both ends of the net were pulled to shore. The net captured 123 white amur. At least 75 additional white amur jumped the net and many more escaped beneath the lead line. The mean weight of fish captured was 8.30 kg, slightly less than those captured in the monofilament gill nets. The smaller mesh size of the modified gill net-haul seine might have accounted for the recovery of smaller fish.

52. This net proved to be an effective white amur removal

technique if a large group of fish could be found. Large bass (>1 kg) and turtles were also captured, but released alive.

White amur weight-
length relationship and growth

53. Plots of weight-length data indicated two distinct white amur size groups were captured. Smaller white amur (450 to 700 mm TL) captured from Lake Baldwin exhibited a weight-length relationship of $\log_{10}(\text{weight}) = -4.821 + 3.005 \log_{10}(\text{length})$ where weight is in grams and TL is in millimetres. White amur > 700 mm TL to 1111 mm TL had a calculated weight-length relationship of $\log_{10}(\text{weight}) = 5.239 + 3.127 \log_{10}(\text{length})$. These two regression equations show that larger white amur are heavier per unit length than smaller individuals. White amur follow closely the cubic relationship of weight to length since regression statistical analysis demonstrated insignificant ($P > 0.05$) differences between the observed slope coefficients and 3.0.

54. After December 1979, white amur over 650 mm TL were sexed by dissection. Two separate weight-length lines were formulated for male and female fish (Figure 20). Significant ($P > 0.05$) differences in slopes were detected between sexes, with females having greater slope coefficients than males. Similarly, the mean K(TL) of females was 1.392, which was significantly ($P < 0.05$) higher than 1.311 recorded for males.

55. Individual white amur growth data from Lake Baldwin were not available. Mean weight and TL of white amur stocked during 1978 were calculated to be 0.79 kg and 408 mm, respectively. Of the 2123 white amur estimated to be in Lake Baldwin by November 1978, 13 percent of the population was left from stockings made in 1975. Growth data were generated by regression techniques based on the mean stocking size and time. Thirteen percent of the largest fish were eliminated from the analysis. Growth of white amur was rapid during the first 2 years of stocking, with fish obtaining a mean weight of 9.17 kg by July 1980 (Table 11). Growth apparently was not as rapid during the second year of introduction as it was during the first year.

56. From the initial stocking in 1975, Colle et al. (1978) found

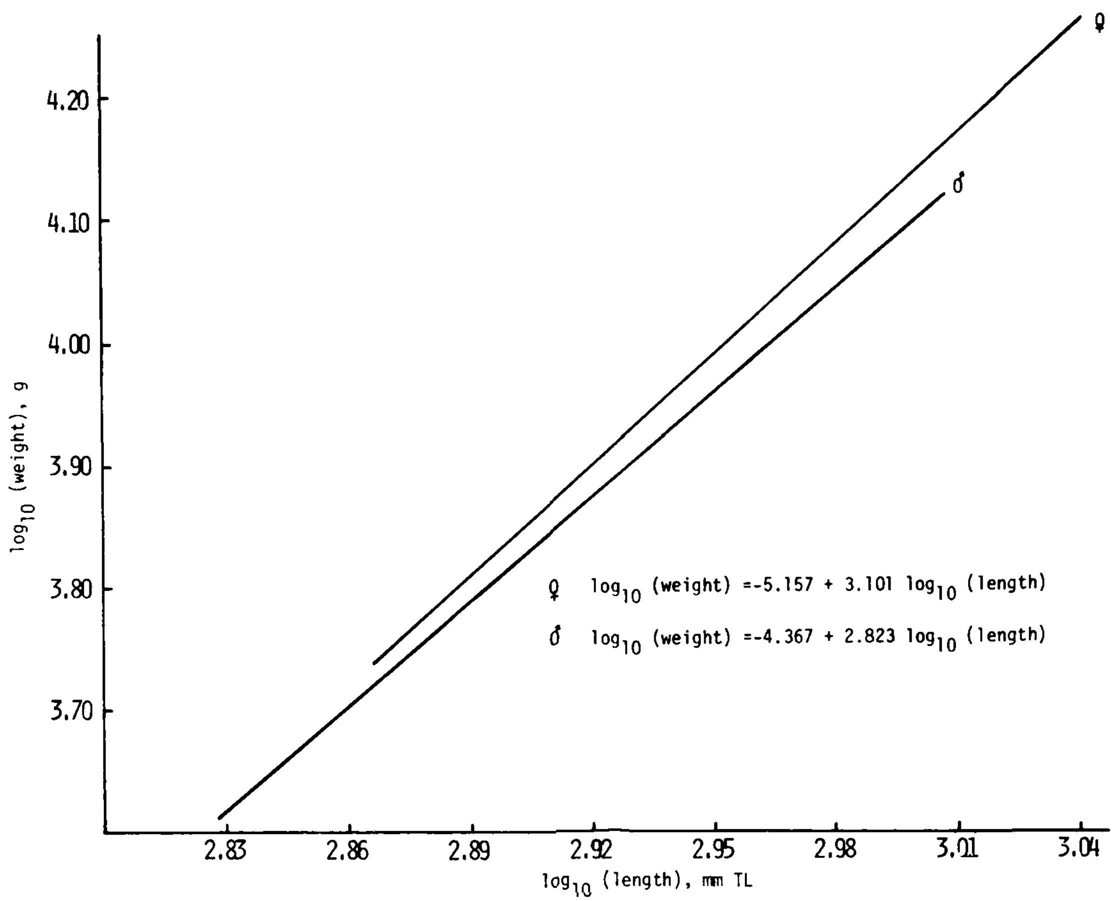


Figure 20. Weight-length lines calculated for female and male white amur captured from Lake Baldwin

that white amur averaged 12.23 kg 2-1/2 years after introduction. In Lake Wales, Florida, white amur demonstrated slower growth than fish from Lake Baldwin (Shireman, Colle, and Macéina 1980). Mean weights of Lake Wales white amur 1 and 2 years after stocking were 3.8 and 7.5 kg, respectively. Fish stocked in Lake Wales were considerably smaller (0.09 kg mean weight) than those introduced in Lake Baldwin.

Calculated hydrilla
comsumption by large white amur

57. Information pertaining to the consumption rates of large white amur (>1 kg) on hydrilla is nonexistent. Small white amur (<300 mm TL) are known to consume their own body weight in vegetation per day. Utilizing standing crop estimates from fathometer calculations and white

amur capture data, consumption was determined for Lake Baldwin white amur (Table 12). The following assumptions were made: (a) hydrilla did not grow during the period from September 1979 to March 1980 although the possibility of dieback was considered, (b) nearly 100 percent white amur survival occurred following stocking, (c) white amur recovered during the sample periods reflected the true mean weight of all fish in the lake, including pre-1978 fish, and (d) standing crop estimates taken with the fathometer were accurate. Calculations showed that large white amur (>6 kg) consume 26 to 28 percent of their body weight in hydrilla wet weight per day. This estimate may be slightly high due to winter dieback of hydrilla. Gut contents of white amur taken from Lake Baldwin during September and December 1979 contained hydrilla which accounted for 8 to 10 percent of the total body weight. Exact 24-hr digestive rates, however, are not known for large white amur. Large white amur (>6 kg) probably exhibit consumption rates between 10 and 20 percent of the body weight per day during optimal feeding conditions.

Hydrilla control by white amur

58. During the summer of 1978, 1845 white amur over 304 mm TL were stocked into Lake Baldwin. A population estimate conducted in the fall of 1977 revealed 278 white amur remained in the lake (Colle et al. 1978). Assuming full survival, 2123 white amur completely eliminated hydrilla in Lake Baldwin, less than 2 years after the 1978 stocking. Maximum hydrilla coverage during 1978 was 78 percent or 62 ha. The successful stocking rate utilized in Lake Baldwin was 34 fish/ha of hydrilla.

59. Hydrilla control was evident by April 1979, when large areas were devoid of vegetation. Following the 1978-1979 winter dieback, hydrilla standing crop increased slightly during the summer of 1979. White amur standing crop was estimated to be 10,000 kg in April 1979, when hydrilla control was evident (Figure 21). Therefore, effective control was obtained with 185 kg fish/ha of hydrilla in Lake Baldwin. A phytoplankton bloom probably aided control by shading hydrilla in water depths greater than 4 m during the summer of 1979. Hydrilla could not be found in the lake after March 1980.

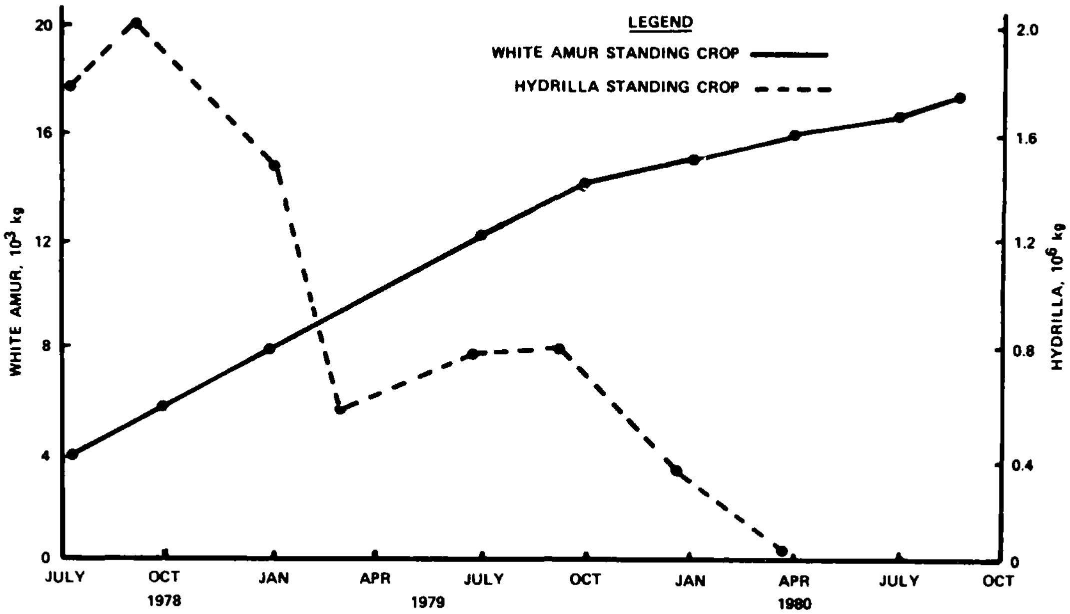


Figure 21. White amur and hydrilla standing crop in Lake Baldwin, Florida, October 1979 through October 1980

60. In Lake Wales, Florida, 10 white amur/ha of hydrilla were not sufficient to control hydrilla in the lake (Shireman and Macéina 1979b and Hardin 1980). Miley, Leslie, and Van Dyke (1979) introduced 50 white amur/ha into three central Florida lakes and virtually eradicated hydrilla in 2 years. These authors, however, reported that the stocking rate utilized resulted in overcontrol of submersed macrophytes.

61. In certain situations, complete elimination of submersed macrophytes may not be desirable to fish populations or water quality in lakes. Ware et al. (1975) found a decline in forage fish abundance associated with the decline in submersed macrophytes in four ponds. Mitzner (1978) and Miley, Leslie, and Van Dyke (1979) observed an increase in phytoplankton and primary productivity following hydrilla removal by white amur. Previous data indicate a stocking rate of 15 to 25 white amur/ha of hydrilla may control, but not eliminate, the plant from the system. Whether control, but not eradication, can be achieved utilizing

white amur for submersed vegetation management remains speculative.

Lake Baldwin native and sport fish

62. Lake Baldwin block nets. Three 0.081-ha block nets were set in Lake Baldwin luring September 1979. Sets were made in habitats with water depth ranging from 2.7 to 3.0 m, 90 to 100 percent hydrilla coverage, and hydrilla 1.0 to 1.3 m below the water's surface. Small sport and forage fish dominated the ichthyofauna in the lake (Tables 13 and 14). Shireman and Haller (1979) report that hydrilla supports high numbers of small forage species. Centrarchids composed 46 and 84 percent, by weight and number, respectively, of the Lake Baldwin fish sample. Large numbers of bluegill and redear sunfish between 81 and 120 mm TL were evident. This probably indicates strong year class strengths due to peak hydrilla infestations observed during 1977 and 1978. Hydrilla provided good spawning cover and reduced predation on young *Lepomis*. Golden shiners (*Notemigonus crysoleucas*) and lake chubsuckers (*Erimyzon sucetta*) were dominant forage fishes by number and weight. Harvestable sport fish composed a small percentage of the total fish biomass.

63. Warm water temperatures and clumped fish distributions may account for the few harvestable bass collected with block nets in Lake Baldwin. Electroshocking revealed large numbers of harvestable (>254 mm TL) bass in the lake. Bluegill, redear, and warmouth (*Lepomis gulosus*) block net size group collections, however, appear to be less biased. Electroshocking gear in Lake Baldwin captured many *Lepomis* sp. but rarely were specimens greater than 175 mm TL encountered.

64. In an operation to remove white amur, 3.19 ha of Lake Baldwin was secured with nets and a 0.18-mg/ℓ treatment of rotenone was applied to the area (see earlier section). It is felt that this concentration was great enough to kill all the largemouth bass in the area. A total of 81 bass over 275 mm TL were collected the night of the treatment, totaling 97.34 kg. This indicates a harvestable bass population of 25 fish/ha and 30.5 kg fish/ha. Average weight of harvestable bass was 1.20 kg.

65. Sport fish length frequencies. Bass length frequencies revealed the 1979 year class to be 126 to 200 mm TL in January 1980, with a mean length of 168 mm (Figure 22). By June 1980, this year class

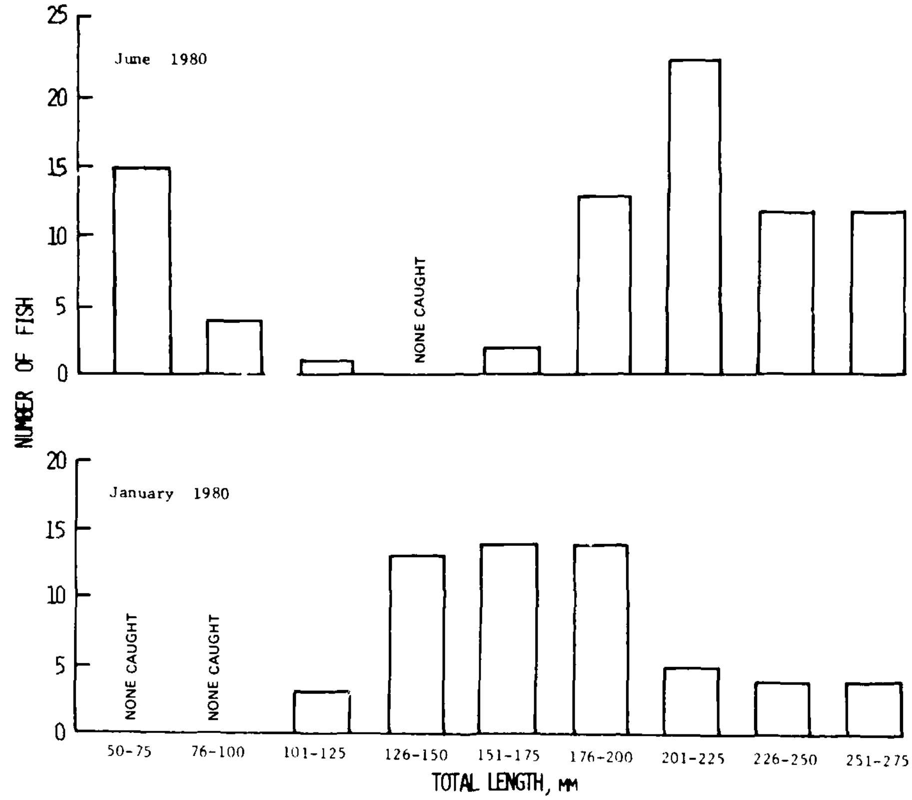


Figure 22. Length frequency histograms of largemouth bass ≤175 mm TL collected by electrofishing, January and June 1980

increased to 176 to 275 mm TL, with a mean length of 210 mm. Growth of first year bass in Lake Baldwin appeared to be good. First year bass collected from a north Florida reservoir in January following a spring spawn attained an average total length of 143 mm (Holland and Chambers, unpublished data). Chew (1974) found 1+ bass (between 1 and 2 years old) in June to be 176 and 214 mm TL from two central Florida lakes. Length frequency data of largemouth bass over 250 mm TL from January and June 1980 electroshock fishing samples and the rotenone treatment during 1980 revealed a strong adult population (Figures 23 and 24). Bass length frequencies between 300 and 500 mm TL were generally distributed evenly, with a decrease in the number of bass over 550 mm.

66. Bluegills increased in length from September 1979 from 81 to 120 mm TL to 151 to 175 by June 1980 (Table 14, Figure 25). Redears

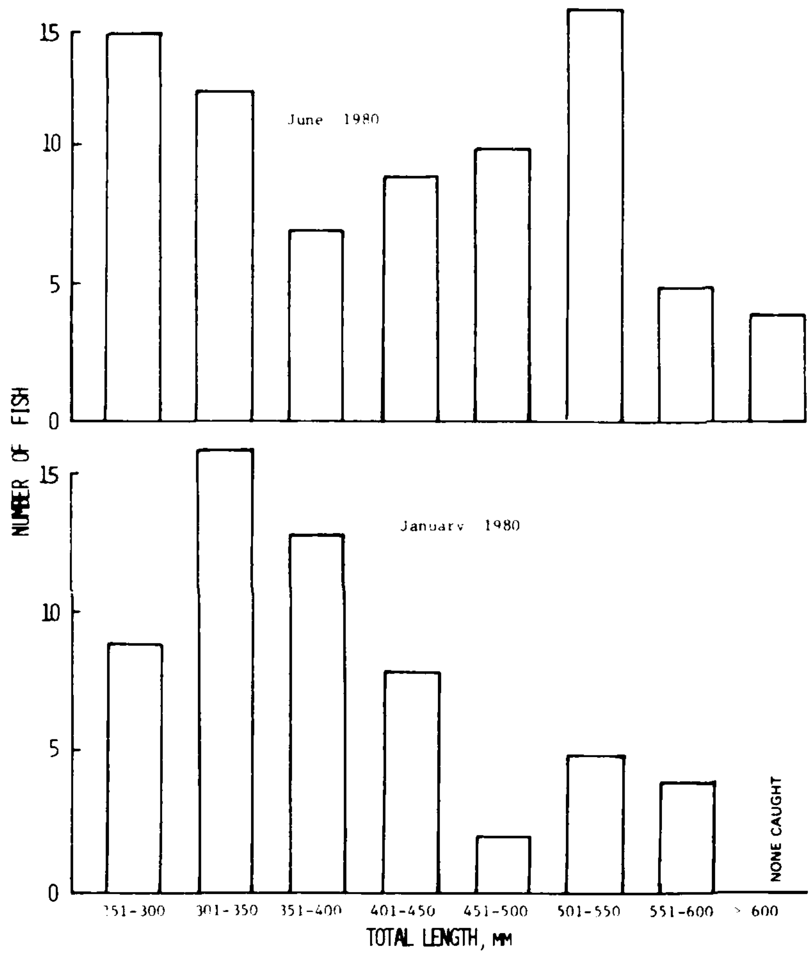


Figure 23. Length frequency histograms of largemouth bass >250 mm TL collected by electrofishing, January and June 1980

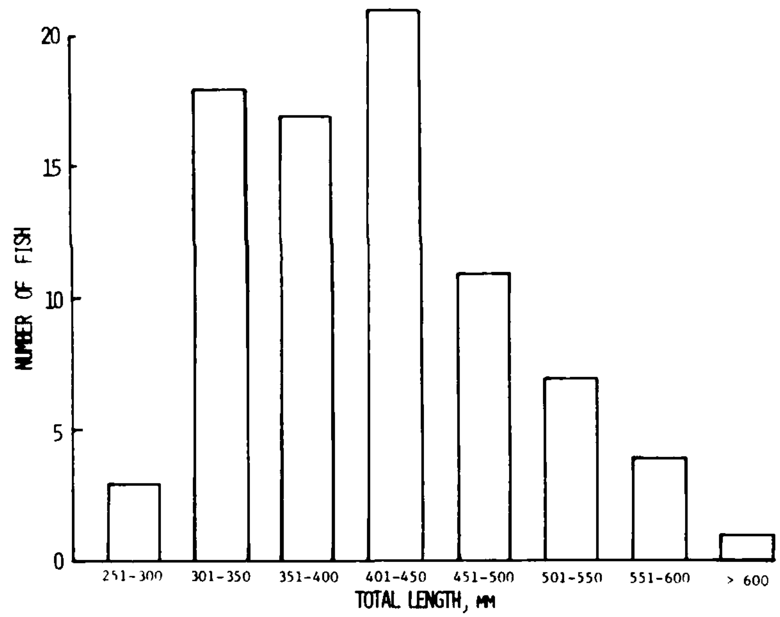


Figure 24. Length frequency histogram of largemouth bass collected during partial lake renovation (rotenone treatment), April 1980

showed a similar size group distribution in September 1979; however, the dominant size group was 126 to 150 mm TL by June 1980 (Table 14, Figure 26). The bluegill and redear populations appear to be stunted in Lake Baldwin, with few fish exceeding 175 mm TL. Strong survival of the 1977 and 1978 year classes due to dense hydrilla infestations may have caused this to occur. Electroshocking conducted in January and June 1980 also revealed very few bluegills less than 75 mm TL inhabiting the lake. Block net sampling in September 1979, however, indicated a total of 975 bluegills/ha in the size range of 41 to 80 mm TL in Lake Baldwin. The rapid decline of hydrilla from 40 percent coverage in September 1979 to complete elimination by March 1980 may have allowed largemouth bass to prey heavily on the bluegills which were previously protected in the hydrilla. The data shown above indicate that Lake Baldwin has a strong harvestable bass population of 30.5 kg/ha.

67. Sport fish condition factors. Condition factors were calculated for largemouth bass, bluegills, and redear sunfish for the summers 1976-1980. Condition factor is a measure of fish well being. Fish with high condition factors usually grow rapidly.

68. Largemouth bass. Bass condition factor values K(TL) from Lake Baldwin were usually lower than the mean of means (1.39) for North America reported by Carlander (1977). Only bass in the largest size class approached or exceeded this value (Table 15), which indicates that conditions in Lake Baldwin were not optimal for bass growth. One hypothesis is that vegetation cover influenced bass condition. When K(TL)'s of bass >151 mm TL are compared among years, K(TL)'s appear to be related to the amount of hydrilla within the lake. Hydrilla coverage was low after chemical treatment during 1976, increased through the summer of 1978, and was nonexistent during 1980. Colle and Shireman (in press) reported that K(TL)'s of bass >150 mm TL declined as hydrilla coverage increased above 50 percent. A similar relationship was noted in Lake Baldwin. Condition factors for bass >151 mm TL were generally higher during 1976 and 1980 when hydrilla was at its lowest ebb. Lowest values were recorded during the summer of 1978, when hydrilla coverage exceeded 60 percent.

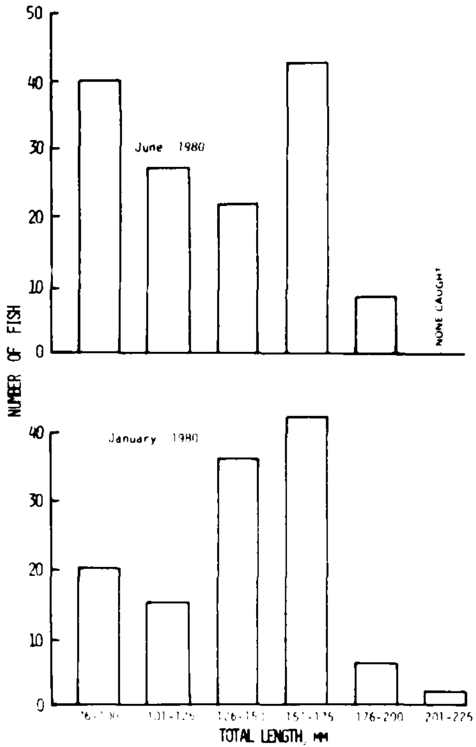
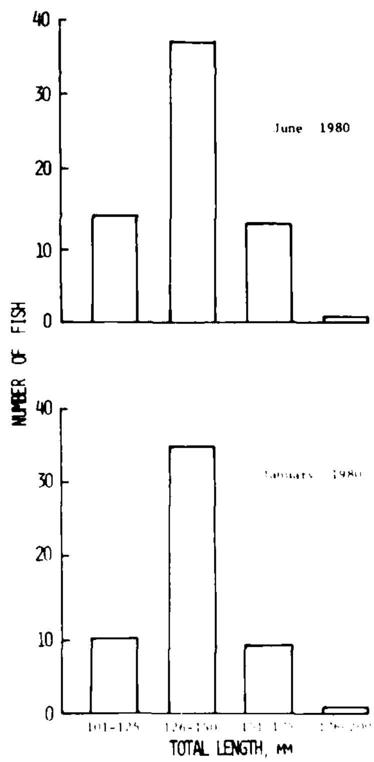


Figure 25. Length frequency histograms for bluegills collected by electrofishing, January and June 1980

Figure 26. Length frequency histograms for redear sunfish collected by electrofishing, January and June 1980



69. Bluegills. Carlander (1977) reported a central 50 percent range for bluegill K(TL)'s of 1.78 to 2.05 based on North America studies. Lake Baldwin bluegill K(TL)'s were lower than the central range reported by Carlander during all years (Table 16). Bluegill K(TL)'s for harvestable fish were greatest during 1977 when hydrilla coverage was expanding.

70. Moderate hydrilla levels, according to Colle and Shireman (in press), can produce a habitat that is reflected in improved K(TL)'s, but as the water column becomes occluded with hydrilla, condition factors are reduced. These conditions were evident in Lake Baldwin during 1977 when moderate levels existed and 1978 when hydrilla increased. Changes in condition are probably related to foraging efficiencies.

71. Redear sunfish. Condition values for redears exhibited trends very similar to those for bluegills (Table 17). As hydrilla levels expanded, K(TL)'s increased (1977) then decreased during peak abundance (1978).

REFERENCES

Almkvist, B. 1975. The influence of flight altitude and type of film on photointerpretation of aquatic macrophytes. Svensk. Bat. Tidskr. 69:181-187.

Benton, A. R., and R. M. Newman. 1976. Color aerial photography for aquatic plant monitoring. Jour. Aquat. Plant Manage. 14:14-16.

Blackburn, R. D. 1975. Aquatic macrophytes and their problems. 164 pages in P. L. Brezonik and J. L. Fox, editors. Water quality management through biological control. Rep. No. ENV-07-75-1.

Carlander, K. D. 1977. Handbook of freshwater fishery biology, volume 2. Iowa State University Press, Ames, Iowa.

Chew, R. L. 1974. Early life history of the Florida largemouth bass. Florida Game and Fresh Water Fish Comm. Bull. 7:76 pp.

Colle, D. E., and J. V. Shireman. In Press. Coefficient of condition for largemouth bass, bluegill and redear in hydrilla infested lakes. Trans. Am. Fish. Soc.

Colle, D. E., J. V. Shireman, R. D. Gasaway, R. L. Stetler, and W. T. Haller. 1978. Utilization of selective removal of grass carp (*Ctenopharyngodon idella*) from an 80-hectare Florida lake to obtain a population estimate. Trans. Am. Fish. Soc. 107:724-729.

Hardin, S. 1980. Selective removal and population estimation of grass carp in Lake Wales, Florida. Fla. Game and Fresh Water Fish Comm. Rep. 17 pp.

Macéina, M. J., and J. V. Shireman. 1980. The use of a recording fathometer for determination of distribution and biomass of hydrilla. J. Aquat. Plant Manage. 18:34-39.

Marking, L. L. 1972. Sensitivity of the white amur to fish toxicants. Prog. Fish-Cult. 34:26.

Miley, W. W., II, A. J. Leslie, and J. M. Van Dyke. 1979. The effects of grass carp (*Ctenopharyngodon idella* Val.) on vegetation and water quality in three central Florida lakes. Fla. Dept. of Natural Resources Final Rept. 119 pp.

Mitzner, L. 1978. Evaluation of biological control of nuisance aquatic vegetation by grass carp. Trans. Am. Fish Soc. 107:135-145.

Shima, L. J., R. R. Anderson, and V. P. Carter. 1976. The use of aerial color infrared photography in mapping vegetation of a freshwater marsh. Ches. Sci. 17:74-85.

Shireman, J. V. 1979. Summary and conclusions. Pages 253-256 in J. V. Shireman, editor. Proceedings of the Grass Carp Conference, Univ. of Florida, Gainesville, Florida, 1978.

Shireman, J. V., D. E. Colle, and M. J. Macéina. 1980. Grass carp growth rates in Lake Wales, Florida. Aquaculture. 19:379-382.

Shireman, J. V., D. E. Colle, and R. W. Rottmann. 1978. Size limits to predation on grass carp by largemouth bass. Trans. Am. Fish. Soc. 107:213-215.

Shireman, J. V., and R. D. Gasaway. 1976. Ecological survey of Lake Baldwin after introduction of the grass carp. Ann. Rep. submitted to Dept. of Navy. 68 pp.

Shireman, J. V., and W. T. Haller. 1979. The ecological impact of integrated chemical and biological aquatic weed control. Ann. Rep. submitted to the Environmental Protection Agency. 239 pp.

Shireman, J. V., and M. J. Macéina. 1979a. Techniques utilizing a recording fathometer in determining distribution and biomass of *Hydrilla verticillata* Royle. Final Rep. submitted to the Corps of Engineers. 94 pp.

Shireman, J. V., and M. J. Macéina. 1979b. Lake Wales, Florida, after introduction of grass carp. Final Rep. submitted to Fla. Dept. of Natural Resources. 79 pp.

Spooner, C. C. 1969. Spectral reflectance of aquarium plants and other underwater materials. Proc. Remote Sensing of the Environment. 6:1003-1011.

Swingle, H. S. 1950. Relationship and dynamics of balanced and unbalanced fish populations. Alabama Agriculture Experiment Station, Bull. No. 274, Auburn, Alabama.

Ware, F. J., R. D. Gasaway, R. A Martz, and T. F. Drda. 1975. Investigations of herbivorous fishes in Florida. Pages 79-84 in P. L. Brezonik and J. L. Fox, editors. Water quality management through biological control. Rep. No. ENV-07-75-1.

Wetzel, R. G. 1975. Limnology. W. B. Saunders Co., Philadelphia, Pennsylvania.

Table 1

Total Hydrilla Volume, ha-m, and Percent of Lake Volume Infested with Hydrilla in Lake Pearl, Florida

Date	Hydrilla Volume ha-m	Percent of Total Lake Volume* Infested with Hydrilla
10 Mar 1980	32.5	68.7
13 May 1980	22.3	47.1
18 Jun 1980	31.9	67.4

* Lake volume = 47.3 ha-m.

Table 2

Best-Fitting Regression Equations Predicting Hydrilla Biomass from Fathometer Characteristics in Three Lakes

Lake	Hydrilla Type	Water Depth Sampled, m	Regression Equation	Total D.F.	Probability >F	r
Pearl	Thick	1.8 to 2.9	Biomass = 7.489 - 2.797 HYDHT - 1.328 ln (HYDSUR)	43	0.036	0.387
Orange	Thick	1.7 to 2.5	ln (Biomass) = 2.361 - 3.431 HYDSUR	12	0.006	0.731
	Sparse	2.0 to 2.7	ln (Biomass) = 3.717 + 0.066 COVER + 1.085 HYDSUR	18	0.006	0.688
Baldwin*	Thick	2.6 to 5.7	Biomass = 1.977 + 1.029 HYDHT - 1.341 ln (HYDSUR)	50	>0.001	0.796
	Sparse	1.6 to 6.2	ln (Biomass) = -5.099 + 0.982 ln (HYDHT) + 1.301 ln (COVER) - 0.281 ln (HYDSUR)	150	>0.001	0.807

Note: Biomass = wet weight of hydrilla in kg/metre^2, HYDHT = height of hydrilla from the hydrosoil to the top of the plant in metres, COVER = percent vertical cover of hydrilla on the tracing, and HYDSUR = the distance from the top of the hydrilla plant to the surface of the water in metres.

* Shireman and Macéina (1979a).

Table 3

Regression Equations Predicting Hydrilla Biomass from Fathometer Tracing Characteristics in Orange Lake. Independent Variables Utilized for Equations Are from Those Calculated from Lake Baldwin (Shireman and Macéina 1979a)

Hydrilla Type	Regression Equation	Probability >F	r
Thick	Biomass = -0.75 + 0.423 HYDHT -2.845 ln (HYDSUR)	0.066	0.648
Sparse	ln (Biomass) = -8.151 + 1.641 ln (HYDHT) +1.970 ln (COVER) + 2.129 ln (HYDSUR)	0.036	0.652

Table 4

Mean Weight-Volume Values of Hydrilla (kg/m^3) in Lakes Baldwin, Orange, and Pearl in Thick and Sparse Hydrilla at Various Depth Intervals. Values in Parentheses Represent Standard Error of the Mean

Hydrilla Type	Depth Strata, m	Lake Baldwin	Orange Lake	Lake Pearl
Thick	1.0 to 1.9	NC	2.88^a (0.52)	3.03^a (0.34)
	2.0 to 2.4	2.98^a (0.03)	2.45^a (0.37)	1.77^b (0.16)
Sparse	1.0 to 1.9	4.51 (0.53)	NC	
	2.0 to 2.9	1.80^a (0.16)	0.54^b (0.21)	

Note: Values with the same letters are not significantly different ($P < 0.05$), based upon Duncan's Multiple Range Test. NC denotes Not Collected.

Table 5

Data Utilized to Construct Hydrilla Volume Hypsographic Curve for Lake Baldwin, Florida

		June 1978			June 1979		
Depth Interval m	Contour Area ha	$\bar{X}$ Water Depth of Interval Sampled, m	$\bar{X}$ Hydrilla Height, m	Area Infested ha	$\bar{X}$ Water Depth of Interval Sampled, m	$\bar{X}$ Hydrilla Height, m	Area Infested ha
0 to 0.9	2.7	0.5*	0.3*	2.7	0.5*	0.3*	2.7
1.0 to 1.9	4.6	1.8	1.3	4.6	1.6	0.9	4.6
2.0 to 2.9	15.8	2.5	1.5	15.8	2.4	1.1	15.8
3.0 to 3.9	9.9	3.4	2.4	9.6	3.4	1.7	9.8
4.0 to 4.9	8.5	4.4	3.6	8.5	4.4	1.5	7.9
5.0 to 5.9	14.6	5.3	2.9	7.2	5.5	1.3	10.8
6.0 to 6.9	21.6	**	**	0	6.1	1.7	2.4
7.0 to 7.9	0.7	**	**	0	**	**	0
	78.4			48.4			54.0

* Estimated.
** Hydrilla not present.

Table 6

Total Hydrilla Volume, ha-m, and Percent of Lake Volume Infested with Hydrilla in Lake Baldwin

Date	Hydrilla Volume ha-m	Percent of Total Lake Volume* Infested with Hydrilla
Jun 14, 1978	106.9	31.0
Aug 2, 1978	133.8	38.8
Nov 11, 1978	135.0	41.1**
Jan 6, 1979	125.0	36.3
Mar 5, 1979	71.5	20.8
Jun 21, 1979	69.8	20.6†

* Lake volume = 344.5 ha-m.
** Water level dropped 0.2 m below mean level; lake volume = 328.6 ha-m.
† Water level dropped 0.1 m below mean level; lake volume = 336.6 ha-m.

Table 7

Mean Weight-Volume Values of Hydrilla, kg/m^3, at Each Depth Interval from Lake Baldwin

Depth Interval m	Number of Samples	$\bar{X}$ Weight kg Hydrilla/m^3	Standard Error
1.0 to 1.9	4	4.51^a	0.53
2.0 to 2.9	55	1.85^b	0.16
3.0 to 3.9	48	1.62^{bc}	0.11
4.0 to 4.9	39	1.45^c	0.11
5.0 to 5.9	50	0.87^d	0.10
6.0 to 6.9	6	0.06^e	0.01

Note: Values with the same letters are not significantly different ($P < 0.05$) based upon Duncan's Multiple Range Test.

Table 8

Submersed Vegetation Data, Lake Baldwin, Florida

Date	Percent Coverage	Percent Volume	Hydrilla Standing Crop kg × 10^5		
			X	L.B.	U.B.
Jun 21, 1979	68.9	20.6	7.96	6.68	9.51
Aug 3, 1979	47.6	15.3	7.90	6.67	9.38
Sep 12, 1979	40.2	13.0	7.81	6.58	9.26
Dec 22, 1979	38.1	8.5	3.62	3.03	4.32
Mar 5, 1980	21.3	1.9	0.32	0.23	0.48
Jun 25, 1980	7.5*	0.4	N.P.	N.P.	N.P.
Sep 15, 1980	>5	>0.1**	N.P.	N.P.	N.P.

Note: L.B. = 95 percent lower bound confidence interval; U.B. = 95 percent upper bound confidence interval; and N.P. = hydrilla not present.

* Filamentous algae *Lyngbya* sp. dominant submersed macrophyte in Lake Baldwin replacing hydrilla.

** Estimate.

Table 9

Summary of White Amur Captures Utilizing Direct Current Electroshock Fishing Gear from Lake Baldwin

Date	Total Number Captured	Number Captured at Night	Effort hr	Catch No./hr	$\bar{X}$ White Amur Weight, kg
Dec 18, 1978	4	4	8	0.5	2.60
Feb 12, 1979	5	5	1.5	3.3	2.45
Apr 12, 1979	6	0	5	1.2	4.45
Jan 8, 1980	7	7	8	0.9	8.60
Jun 30, 1980	7	7	9	0.8	13.90
	29	23	31.5	0.9	

Table 10

White Amur Captures from Lake Baldwin Utilizing Monofilament Gill Nets

Date	Total Number Captured	No. Captured for Each Size of Stretch Mesh, mm			$\bar{X}$ Weight kg	Hours Fishing	Metres of Net	No. Captured per 12 hr per 100 m of Net
		15.2	20.3	25.4				
Sep 5-6, 1979	7	1	6	NU	7.65	32	183	1.43
Dec 21-22, 1979	20	NU	17	3	9.75	26	274	3.37
Jan 8, 1980	8	NU	4	4	9.20	14	206	3.33
Jan 30, 1980	26	NU	23	3	8.40	13.5	297	7.78
Mar 10, 1980	22	NU	19	3	10.40	9	297	9.88
Mar 26, 1980	8	NU	6	2	10.05	12.5	274	2.80
Jun 17-18, 1980	2	NU	1	1	12.60	24	274	0.36
Jun 24-25, 1980	2	NU	2	0	11.35	22	274	0.40
Aug 26-27, 1980	2	1	1	0	12.35	23	366	0.29
Sep 15-16, 1980	0	NU	0	0	--	24	274	0.00
	97					200	2719	2.14*

Note: NU = not used.
* Overall mean.

Table 11

White Amur Growth Generated by Regression from Lake Baldwin

	Years Following Stocking				
	0	1/2	1	1-1/2	2
$\bar{X}$ weight, kg	0.79	3.00	5.24	7.27	9.17
Growth, kg		2.21	2.24	2.03	1.90
$\bar{X}$ length, mm TL	408	592	720	807	876
Growth, mm TL		184	128	87	69

Table 12

Data and Calculations Utilized to Determine Hydrilla Consumption by Large White Amur in Lake Baldwin

	Date		
	Sep 12, 1979	Dec 22, 1979	Mar 11, 1980
Number of white amur	2,123	2,123	2,050
$\bar{X}$ weight white amur, kg	6.60	7.18	7.85
White amur standing crop, kg	14,000	15,250	16,100
Hydrilla standing crop, kg	781,320	362,450	32,370

	Time Interval	
	Sep 12, 1979, to Dec 22, 1979	Dec 22, 1979, to Mar 11, 1980
White amur standing crop, kg	14,625	15,675
Interval, days	101	80
Hydrilla standing crop decline, kg	418,870	330,080
Consumption, percent/day (wet wt. hydrilla consumed/day/fish wt. during given interval)	28%	26%

Table 13

Mean Number and Mean Weight of Forage Fish Collected from 0.081-ha Block Nets in Lake Baldwin, September 1979

Species	Size Group mm TL	No./ha	Weight g/ha
Golden shiner			
Notemigonus chrysoleucas	81 to 120	8	87
	121 to 160	82	2,049
	161 to 200	453	26,280
	201 to 240	535	51,439
	241 to 280	95	15,398
	281 to 320	12	3,033
		1,185	98,286
Bluespotted sunfish			
Enneacanthus gloriosus	0 to 40	25	16
	41 to 80	156	453
		181	469
Brown swamp darter			
Etheostoma fusiforme	41 to 80	16	6
Bluefin killifish			
Lucania goodei	0 to 40	29	8
Lake chubsucker			
Erimyzon sucetta	201 to 240	21	3,067
	241 to 280	16	3,582
	281 to 320	4	1,656
	321 to 360	12	6,273
		53	14,578
Total Forage Fish		1,464	113,347

Table 14

Mean Number and Mean Weight of Sport Fish Collected from 0.081-ha Block Nets in Lake Baldwin, September 1979

Species	Size Group mm TL	No./ha	Weight g/ha
Largemouth bass			
Micropterus salmoides	41 to 80	25	89
	81 to 120	21	260
	121 to 160	12	164
	161 to 200	29	1,668
	201 to 240	8	916
	241 to 280	16	2,951
	281 to 320*	4	1,343
		115	7,391
Bluegill			
Lepomis macrochirus	40 to 80	975	5,823
	81 to 120	3,786	40,588
	121 to 160	202	6,567
	161 to 200*	12	800
		4,975	53,778
Redear			
Lepomis microlophus	41 to 80	4	26
	81 to 120	1,037	14,940
	121 to 160	128	3,327
	201 to 240*	12	1,410
	241 to 280*	8	1,903
		1,189	21,606
Black crappie			
Pomoxis nigromaculatus	81 to 120	8	100
	121 to 160	70	2,317
	161 to 200	99	5,363
		177	7,780
Warmouth			
Lepomis gulosus	0 to 40	230	117
	41 to 80	765	2,883
	81 to 120	156	2,696
		1,151	5,696
Total Sport Fish		7,607	96,251
Total Harvestable*		36	5,456

* Harvestable fish as defined by Swingle (1950): Bluegill, redear, and warmouth >150 mm TL; black crappie >228 mm TL; largemouth bass >254 mm TL.

Table 15

Mean Condition Factor K(TL) , Total Length TL , and Number N of Largemouth Bass Collected from Lake Baldwin During the Summers 1976-1980. Numbers in Parentheses Represent Standard Error of the Mean

Size Group TL, mm		Years: Summer 1976	Summer 1977	Summer 1978	Summer 1980
<75	$\bar{X}$ K(TL)	1.44^{a} (0.16)	1.20^{a} (0.12)	1.24^{a} (0.07)	1.32^{a} (0.04)
	$\bar{X}$ TL	62	55	61	51
	N	2	16	4	16
75 to 150	$\bar{X}$ K(TL)	1.16^{a} (0.02)	1.15^{a} (0.04)	1.24^{a} (0.04)	1.10^{a} (0.04)
	$\bar{X}$ TL	112	98	118	91
	N	34	14	8	4
151 to 250	$\bar{X}$ K(TL)	1.27^{a} (0.06)	1.20^{b} (0.01)	1.09^{c} (0.01)	1.18^{b} (0.01)
	$\bar{X}$ TL	178	222	201	210
	N	13	24	49	50
251 to 350	$\bar{X}$ K(TL)	1.24^{ab} (0.09)	1.29^{a} (0.03)	1.11^{b} (0.03)	1.26^{a} (0.03)
	$\bar{X}$ TL	332	286	301	290
	N	5	16	31	26
$\geq$350	$\bar{X}$ K(TL)	1.52^{a} (0.11)	1.32^{b} (0.02)	1.32^{b} (0.06)	1.55^{a} (0.02)
	$\bar{X}$ TL	455	448	450	490
	N	10	19	12	50

Note: Yearly means followed by the same letter are not significantly ($P < 0.05$) different.

Table 16

Mean Condition Factor K(TL), Total Length TL, and Number N of Bluegill Collected from Lake Baldwin During the Summers 1976-1980. Numbers in Parentheses Represent Standard Error of the Mean

Size Group TL, mm		Years: Summer 1976	Summer 1977	Summer 1978	Summer 1980
50 to 100	$\bar{X}$ K(TL)	1.55[a] (0.03)	1.31[a] (0.03)	1.49[a] (0.0[illegible])	1.39[a] (0.01)
	$\bar{X}$ TL	75	74	86	93
	N	41	50	51	40
101 to 150	$\bar{X}$ K(TL)	1.39[c] (0.02)	1.47[b] (0.02)	1.49[b] (0.01)	1.55[a] (0.01)
	$\bar{X}$ TL	124	136	127	126
	N	34	43	52	48
$\geq$151	$\bar{X}$ K(TL)	1.57[b] (0.03)	1.75[c] (0.03)	1.63[b] (0.02)	1.60[b] (0.03)
	$\bar{X}$ TL	182	194	184	167
	N	49	44	42	50

Note: Yearly means followed by the same letter are not significantly ($P < 0.05$) different.

Table 17

Mean Condition Factor K(TL), Total Length TL, and Number N of Redear Collected from Lake Baldwin During the Summers 1976-1980. Numbers in Parentheses Represent Standard Error of the Mean

Size Group TL, mm		Years			
		Summer 1976	Summer 1977	Summer 1978	Summer 1980
50 to 100	$\bar{X}$ K(TL)	1.47^{a} (0.04)	1.48^{a} (0.03)	1.40^{c} (0.02)	NC
	$\bar{X}$ TL	82	64	89	
	N	6	36	16	
101 to 150	$\bar{X}$ K(TL)	1.51^{ab} (0.25)	1.45^{b} (0.02)	1.41^{b} (0.02)	1.53^{a} (0.02)
	$\bar{X}$ TL	114	141	122	132
	N	3	27	51	50
J151	$\bar{X}$ K(TL)	1.48^{b} (0.11)	1.78^{a} (0.04)	1.56^{b} (0.03)	1.54^{b} (0.03)
	$\bar{X}$ TL	214	214	184	159
	N	18	45	13	14

Note: Yearly means followed by the same letter are not significantly ($P < 0.05$) different. NC = not collected.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Shireman, Jerome V.
Recording fathometer techniques for hydrilla distribution and biomass studies / by Jerome V. Shireman, Michael J. Macéina (Aquatic Plants Research Center, Institute of Food and Agricultural Sciences, University of Florida). -- Vicksburg, Miss. : U.S. Army Engineer Waterways Experiment Station ; Springfield, Va. : available from NTIS, 1983.
43, [13] p. : ill. ; 27 cm. -- (Miscellaneous paper ; A-83-1)
Cover title.
"January 1983."
Final report.
"Prepared for U.S. Army Engineer District, Jacksonville and Office, Chief of Engineers, U.S. Army under Contract No. DACW39-80-C-0035."
"Monitored by Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station."

Shireman, Jerome V.
Recording fathometer techniques for hydrilla : ... 1983.
(Card 2)

At head of title: Aquatic Plant Control Research Program.
Bibliography: p. 42-43.

1. Aquatic plants. 2. Fishes. 3. Lakes. I. Macéina, Michael J. II. United States. Army. Corps of Engineers. Jacksonville District. III. United States. Army. Corps of Engineers. Office of the Chief of Engineers. IV. Aquatic Plant Control Research Program. V. U.S. Army Engineer Waterways Experiment Station. Environmental Laboratory. VI. Title VII. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; A-83-1.
TA7.W34m no.A-83-1

4-8

DTI